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ELEMENTS

OF

PHYSIOLOGY;

D.r LUIGI
ZANGRANDI

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VIENNA, PETERSBURGH, MADRID, TURIN, &c.

THE FIFTH EDITION, REVISED, CORRECTED, AND ENLARGED.

Γνῶθι σεαυτον.

TRANSLATED FROM THE FRENCH,
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THE

TRANSLATOR's PREFACE.

IT is a singular fact, that, in this country, which has given birth to some of the most important discoveries in Physiology, there should not have been produced a single elementary or systematic work on the subject. Those only have written on Physiology, who had discoveries to make known, and to these they have, in general, confined their publications. The consequence has been, that there are, in the English language, many works in different departments, and on single points, of physiological inquiry, and that our miscellaneous scientific publications, the transactions of Societies and periodical works of inferior importance, are stored with much valuable matter, both of new facts and original speculation. But till this is brought together, from the various quarters where it lies scattered, into some more comprehensive form, it is not truly within the reach of those to whom it would furnish an important part of their professional knowledge; nor indeed, until it possesses some systematic work, embracing all that is known of the subject, can the country itself exhibit its claims on the scientific world for the service it has done to Physiology.

Such a work, however, which should fairly represent the state of Physiology, as it at present exists in Europe, was perhaps scarcely to be expected: for, though it should contain no discovery, it would be, if rightly executed, a work of great magnitude, and requiring qualities, which do not often go together. The industry requisite for collecting materials from so great a number of writers in different languages—the judgment and profound knowledge of the subject necessary in the selection—the acuteness required in arriving at the truth, where the variety of opinions is so great, are qualities rare in themselves, and still more rarely combined. The genius, which inspired to the great English Physiologists the important discoveries that have immortalized such names as Harvey, Hunter, Monro, seems as if it had unfitted them for the more laborious and ungracious task of compiling and arranging the discoveries of others. How seldom may we expect to meet with such a combination of genius and indefatigable industry, as was seen in the great Haller; yet without a certain degree, at least, of the same qualities, no writer can pretend to tread in his footsteps.

It is probable too, that the great work itself of Haller, at the same time that it best illustrates the importance of the undertaking, and its difficulty, must be considered as having long remained, by its excellence, an impediment to the production of a similar succeeding work. Haller was fifty years engaged in the most ardent study of Physiology; his work, besides all that he himself, the great leader in physiological discovery, and also the most extensive discoverer, wished to give to the world, of his own, contained all that was known on the subject, at the time it appeared. As it was written too, in the Latin language, it found a ready access to every school of Medicine, and was every where received by the Profession as, at once, the most authentic record of the facts of Physiology, and the most luminous exposition of the principles of the science. We cannot wonder, therefore, that, while Haller had exclusive possession of Physiology, no other writer should have attempted any work on the same subject, even for some time after his death, while the additions to the mass of knowledge were not sufficient to effect any important change in the science. Now, however, enough has been added to change, in many important respects, the face of the science, and to demand systematic arrangement. Of late years, accordingly, several works, composed with this view, have appeared on the Continent; amongst which may be mentioned those of Blumenbach, Bichat, Dr. Dumas of Montpellier, and M. Richerand.

This priority in the systematic arrangement of our knowledge does not, however, at all imply that the progress of Physiology abroad has been more rapid than in this country. It would be difficult to say where it is furthest advanced. If a comparative view were to be given of the science, as it exists in Britain and on the Continent, it would rather appear that a different excellence has been attained on either side, accompanied, of course, by different defects. In Britain, it might be shown that it is founded on sounder principles, and more freed from the doctrines of the older Physiologists, who were rather given to invent explanations of the phenomena of Nature, than to seek them in the laborious investigation of her operations. The Physiologists of this country have studied with intelligent, patient, and zealous research, the facts of Physiology; they have distinguished themselves in this, as in the other sciences, by an anxiety for exactness of knowledge. The continental Physiologists are fond of theory: an adherence even to the old theories characterizes, very remarkably, the works of the most modern foreign writers on Medicine and Surgery, influencing even the practice of the Profession in a very unfavourable manner. But this spirit of theorizing, this anxiety to extend individual facts into general principles, is as essential to the progress of the Science, as that zeal in the acquisition of knowledge which prepares its materials. They carry this spirit to excess: but which is the most dangerous error to science, I will not pretend to determine—that impatient activity of mind, which, in its eagerness to theorize, will not wait for fulness of knowledge, or that over-distrust of theory, which is not judicious caution, but timidity, or indolence, or a real want of intellectual disposition to high philosophic speculation.

The same comparison would shew a superiority in another respect, in the Physiologists of this country; that they have made further progress in *pathological* Physiology. They have more applied themselves to the study of Nature under disease, investigating both the disordered functions and the altered structure of disease, and seeking to understand, and successfully availing themselves of the powers of renovation and substitution, which are provided in the body for injuries of its original organization; drawing, in short, from Physiology, a light to the intelligence and practice of their Art. The continental Physiologists, on the other hand, have more endeavoured to bring light from other sciences to Physiology. And though, here too, their speculations have borne the same character of precipitancy, there is no doubt their labours in this department have been attended with considerable success; and that while many of their applications and analogies have passed away from the public mind, almost as soon as they were before it, much still remains, that will be permanently received as convincing illustration, from the sciences of inanimate matter, of the processes of living Nature *

This different direction of the spirit of inquiry, in different countries, has probably been favourable to the rapid progress of the Science. Yet something has been lost to it, by what was not at all a necessary consequence of such a division of labour, a disregard of each others pursuits and acquisitions. Both here and abroad, we have every day discoveries brought forward by writers, who are very legitimate discoverers, if real ignorance of the previous knowledge of others entitle to the name of originality. These imagined discoveries are prosecuted with infinite zeal, and much good labour is lost to Physiology, in bringing facts to light, that were well established in the world, before these authors were born. The work, now given to the public, can scarcely be offered as a remedy, as far as this country is concerned, of the inconvenience: for though it contains a good summary of the knowledge and opinions of modern Physiologists, and does very fairly represent the present state of the Sci-

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* It was in the contemplation of the Translator, when he undertook this work, to have engaged, in some degree, in the comparison of which he has here spoken. He intended to annex to it, in the form of an Appendix, a comparative view of the opinions entertained in this country, and on the continent, on many interesting points of Physiology: which might serve the purpose of notes to the work, and be some compensation to himself for the unsatisfactory labour of translation. It is not till towards the close of the work, of which the translation and printing have been unavoidably going on together, that he finds the time to which it was of importance to the publisher to fix the publication, does not allow him to complete his original intention.

ence on the Continent, those, who really desire to possess themselves of what has been done there, will be aware that they must undertake a much more laborious study, and seek for the information they want, in most cases, at its original sources.

This work, I believe, will be chiefly useful for the purpose which was designed by the author,—as an elementary book for students. There is not, as I have said, one English elementary work on Physiology; scarcely indeed on any part of our professional knowledge. Whether it be that there is more literary industry abroad, or that in the Institutions for Medical Education the public Teachers are more separated from their profession, and devoted to the duties of Instruction, it is certain that in all departments of professional study, they have distinguished themselves by the number and ability of their elementary works: and in the science of Physiology, in particular, the English student, who is desirous of engaging in it, will find himself at a loss for a guide, among the names that have done honour to science at home, and compelled to seek assistance, in his pursuit, from the writers of other countries.

An eloquent modern writer on Anatomy, complains that too much attention is now bestowed on Physiology, while Anatomy, on which sound Physiology ought to rest, is neglected. That Anatomy ought to be made the ground work of all medical education, and that a thorough knowledge of the structure of the human body ought to precede the study of its functions is indisputable, nor does the truth of this opinion appear to be denied by any one in the present day. And accordingly Anatomy appears every where to be cultivated with ardour. In all places of medical education, the number, both of teachers and students of Anatomy, is increased in much greater proportion, than in any other department of professional study. Dissection is now considered as essential in the study of Anatomy, and almost a new system of minute surgical Anatomy has been instituted within a few years.

There appears no reason then, to complain that Anatomy has been neglected; and if there were, it is not to Physiology, the neglect could be imputed. The number of teachers of Anatomy, of Medicine, and Surgery, is more than four times what it was, half a century ago, but the number of teachers of Physiology remains nearly the same. Physiology is either not taught at all, or forms a very insignificant part of a course of Anatomy. A professed course of Physiology is, at present, scarcely delivered any where out of the Metropolis, and even there, only one Lecturer is found to undertake such a course. It is not true that, in this country, Physiology absorbs too much of the attention of students, and interferes with more important studies; it may rather be said to be too little attended to as a branch of instruction; it is omitted until the engagements of the profession leave no time for the prosecution of a laborious study, and it is, in the end, neglected altogether. If Physiology, if the knowledge of the healthy functions be necessary to him whose object in life is to understand the functions of the body in disease, it is of consequence that Physiology be more generally studied; that it be considered more as an essential object of professional education; that our public teachers bestow on it a greater share of their attention.

Let it not be objected to the public teaching of Physiology, that it may be learnt from books, as well as from lectures. The objection if valid, would be equally applicable to most of the other departments of professional study, the objects of which do not admit of ocular demonstration; yet no one objects to lectures on Medicine, Materia Medica, &c. This study, however, does require the frequent illustration of Anatomy, of drawings, of preparations, and even of experiments which are within the reach of few. The study of Physiology, in books alone, is dry and uninteresting to the young student, and will never be prosecuted with ardour. It seems too much to rely on the capacity for solitary study of young minds; and at all events, the study of Physiology, as of any other science, by a number of young men, under one teacher, will be more ardent, from the frequency of discussion and experiment, than if carried on by each separately. To study Physiology with any effect, the student should have access to public lectures on the subject, in which he will see experiments and preparations, besides such dissections in human and comparative Anatomy, as may be required to illustrate the doctrines he hears, he will then be qualified to turn his private studies to account, and will pursue them with interest.

Haller, who may justly be termed the Father of Physiology, was himself a distinguished lecturer, and his mode of instruction may be safely followed. He was a pupil of the celebrated Boerhaave, and when he himself became a public teacher, the doctrines of that great man, had possession of the schools; these doctrines, he tells us, in his preface to the Primæ Lineæ Physiologiæ, he continued to teach, for twenty-four years, using the work of his illustrious teacher, as he calls him, for his text book; but finding that since the time of Boerhaave, many improvements and discoveries had been made in the science, he thought it right to substitute an elementary work of his own; containing the more recent discoveries, and this work he addressed to his class. Physiology is improving, and new discoveries are daily added to the store of knowledge already in our possession; if all these scattered materials were brought together, a work might be grounded on them of the highest value to the public teacher, who has to communicate instruction, and to the student, who has to meditate in private and at leisure, on the knowledge that has been rapidly communicated to him in a public lecture. This object is, as was already observed, in part fulfilled by the work of M. Richerand, though incompletely, as far as respects this country, as it does not embrace sufficiently the state of the science in Britain.

Birmingham, September 14, 1812.

THE

AUTHOR'S ADVERTISEMENT,

TO THE

*FIFTH EDITION.**

IN preparing for the press this Fifth Edition of his work, the Author has carefully revised and corrected it, in all its parts, so as to render it more worthy of the success it has already obtained. The additions which have been made, will be found not to consist of idle discourses, or frivolous hypotheses. The groundwork and the order are the same, the Author has merely added to the mass of facts,—supported, by additional proofs, the opinions which he had advanced,—and developed those parts of his subject, which, from being explained in too concise a manner, might be involved in some degree of obscurity.

Among the variety of opinions which criticism, oftener unjust than enlightened, has pronounced, in judging this work, there is one which requires to be refuted, because it proceeds from an erroneous idea of what an elementary work should be. The Author, it has been said, ought to have contented himself with giving a view of the present state of the science, without any additions of his own, and he should have abstained from inserting new opinions, which, until they had received the sanction of the learned world, ought not to have been introduced into an elementary work. This objection may be answered, by considering that modern Physiology being, in some measure, a new and regenerated science, there will be found, in treating of it to its full extent, many deficiencies to be filled up, and many doctrines evidently erroneous, for which truths are to be substituted, which it is of importance to discover. Lavoisier, in his Elements of Chemistry, set forth, in a methodical order, truths which he himself had discovered; he introduced original ideas, not such as owe an appearance of originality, to minute explanation of what is already known, or to a general want of erudition, too prevalent in the present day. One of his most illustrious colleagues, in describing the state of the science, has likewise given a history of his discoveries and labours, and men of the soundest judgment ascribe the astonishing progress of chemistry, in great measure, to the favourable circumstance of our possessing elementary works written by the most distinguished chemists.

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* Published 1811.

The present work has been translated in England, in Spain, in Italy, in Germany, and men of merit have not disdained the task: amongst others, I may mention Mr. Robert Kerrison, Member of the Royal College of Surgeons in London, author of a translation of these Elements of Physiology, published in the year 1803.

Since the publication of the Fourth Edition of this work, Professor Sprengel has published his Institutes of Physiology*. The date of that new work, and the well deserved reputation of its author, entitle it to be considered as a faithful account of the state of physiological sciences, in Germany. In that work, the reader will be astonished to find it stated that every thing in the human body, is governed by *polar influence*, and by the laws of *antagonism*; that man is in a state of *positive electricity*; that his body is formed chiefly of *oxygen;* while the female body is in a state of *negative electricity*, with a superabundant quantity of *hydrogen* in the composition of its solids and fluids. Thus, by the premature application of a few facts, borrowed from the physico-chemical sciences, the learned of Germany, have thrown back Physiology into the uncertainty of conjectures and hypotheses.

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* *Institutiones physiologicæ.* Amstelod. 1809, 2 vols. 8vo.

On the other hand, Gall, by his anatomical discoveries on the organization of the brain and nerves, and a few other Physiologists, by their experiments on living animals, have been usefully employed in advancing the progress of Physiology. The author has been anxious to increase the value of this new edition, by adding to it the result of their observations.

As to those who, determined on being Authors, in*vitâ Minervâ* write on sympathy, only to add to the obscurity of the subject, that of their own style and ideas, or who, in treating of the important subject of secretion, find only an occasion of displaying their stupidity, the author is forced to confess, that, to him it appears difficult to unite to a more hopeless mediocrity, pretensions more truly ridiculous.

PREFACE

TO THE FIRST EDITION.*

THESE Elements of Physiology, which contain an abstract of the doctrines I have taught, for several years past, in my public lectures, are written on the model of the small work on physiology of the great and immortal Haller (Primcæ linæ Physiologiæ). I am far, however, from presuming to say that I have equalled the merit of a work, which, as is remarked by a man of the highest ability,† when it appeared, gave a new aspect to the science, and commanded universal approbation. If these new Elements of Physiology deserve any preference over that work, the honour is not due to the Author, but to the times in which he writes, enriched, by the progress of the physical sciences, with a multitude of data and results which may be said to have rendered Physiology altogether a new science.

It will be easily perceived that the plan I have adopted differs essentially from that followed by several respectable physicians; and that the treatises on Physiology, most lately published, resemble the present, only in their title. In combining a great number of facts, in adding to those already known, the result of my own observation and experience, and in connecting them, by a method that should unite accuracy and simplicity, I have had it in view to keep a due measure between those elementary works, whose conciseness approaches to obscurity and dryness, and those in which the authors, omitting no detail, and exhausting, in a manner, their subject, seem to have written only for those who have leisure or inclination for the profoundest study.

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* Published in 1801.

†"When Haller published his *Primæ lineæ Physiologiæ*, which he valued most of all his works, a considerable sensation was excited in the schools. In works on the same subject, it was customary to find long dissertations, almost always void of proof, extraordinary opinions, or brilliant fictions. It was matter of wonder, that in Haller's work, there should be found only numerous facts, precise details, and direct inferences, &c."

VICQ-D'AZYR.

Should any conceive that the present undertaking is above the capacity of my age, I will say, even at the risk of a paradox, that young men are perhaps fittest to compose elementary works; because the difficulties they have encountered in the study, are yet fresh in their memory, as well as the steps which they have taken to overcome them; and further, because their recent experience points out to them the defects and advantages of the different methods of other instructors;* so that he, who, in the shortest space of time, has carried to the greatest extent his own acquisition of sound knowledge, will, in some respects, be the best guide to his successors, in the difficult and perplexing paths of elementary study.

In the composition of the work, I have borne constantly in mind the necessity of sacrificing elegance to clearness, which I know to be the most important merit of an elementary treatise. Further, I have throughout followed, I believe, the same arrangement in the succession of the subjects, and applied to the science of living man, the principle of the Association of ideas; a principle so well developed by Condillac, in his Treatise on the Art of Writing, and to which that philosopher has shewn, that all the rules of the art are to be referred. Notwithstanding the rigorous law to which I have subjected myself, I have, after the example of the ancients, and, among the moderns of Bordeu, and of several other physicians and physiologists of equal celebrity, thought myself justified in employing, when I felt it necessary, metaphorical expressions; because, as has been justly observed by a writer who has been, in our own times, an honour to her sex; if conciseness do not consist in the art of reducing the number of words; still less does it consist in depriving language of imagery. The conciseness which is to be envied, is that of Tacitus, at once eloquent and energetic; and, far from any fear that imagery should injure that justly admired compression of style, figurative expressions are, indeed, those which comprise, in fewest words, the greatest sum of ideas.*

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* "The best order in which truth can be set forth, is that in which it might naturally have been discovered; for, the surest method of instructing others, is to lead them along the path which we ourselves have followed, in our own instruction. In this way, we shall seem not so much to lay before them our own knowledge, as to set themselves on the search and discovery of unknown truths."

CONDILLAC.

Those who insist on meeting, in a work on Physiology, with a romance instead of the history of the animal economy, will, no doubt, reproach me with having entirely neglected a great number of hypotheses, ingenious or absurd, on the uses of organs; with having omitted, for example, while speaking of the spleen, to mention the opinion which considers that viscus as the seat of mirth and laughter; with having said nothing of the opinion of those authors who conceive it to maintain, by counterpoizing the liver, the equilibrium of the two hypochondria, nor even of the doctrine of the ancients who ascribed to it the secretion of the atra bilis, &c. To recall such errors for the sake of elaborate refutation, would be wasting much precious time in idle discussions, and possessing, as Bacon calls it, the art of making one question bring forth a thousand, by answers more and more unsatisfactory. I have chosen to forego all such vain parade, from a clear conviction, that works of merit are as often distinguished by some things that are not to be found in them, as by those they do contain.

Several authors, in treating of the science of man, have indulged themselves in frequent excursion into the vast field of accessory sciences, and have, without necessity, incorporated in their works, whole chapters on air, on sound, on light and other subjects, which belong to the department of natural philosophy and chemistry. Haller himself is not entirely free of blame, for having discredited Physiology by this borrowed display. I have introduced only such general ideas of the subject, as were absolutely necessary to render my own intelligible, and were, indeed, too closely connected with it, to admit of separation.

One of the principal faults of writers on Physiology is, that they are apt to fall into frequent repetitions; and that fault is often owing to the difficulty of settling satisfactorily, the limits of actions which are mutually connected and dependent among themselves, and running into each other, like those that are carried on in the animal economy.

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* *De la Littèrature considérê dans ses rapports avec les Institutions Sociales*, par Madame de Stael-Holstein, tome II.

" In composition, one should avoid prolixity, be" cause it is fatiguing to the mind ; digressions, be" cause they divert the attention ; frequent divisions " and subdivisions, because they are perplexing ; and " repetitions, because they are oppressive. What has " been once said, and in its proper place, is clearer, " than if several times repeated elsewhere."* In following these precepts, and they cannot be too much attended to, one may, it is true, incur the risk of being thought superficial, by superficial readers, who form their opinion of a work from the perusal of a single chapter, but a most ample compensation will be found in the opinion of those, who choose to be thoroughly acquainted with a work, before they pass on it their final judgment.

After having stated in what spirit this work has been written, I may say something of the motives which have led to its publication. I would mention, in the first place, the advantage which, it might be expected, would accrue to the science and to those who are engaged in its pursuit,--and, in the next place, the satisfaction which study has in store for him, who bestows on it the time he can snatch from the laborious practice of our art. In his short intervals of leisure from public instruction, and from professional duty, left to himself and his own thoughts, in the silence of study, and in the calm of meditation, he looks down, with an eye of pity, on those who drag on, through the lowest intrigues, a despicable existence, and finds his consolation against the endless vexations, that are prepared for him by supercilious ignorance and jealous mediocrity.

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* Condillac *Essai sur l'Origine des Connoissances humaines*, seconde partie, sect. ii. chap. iv.

PRELIMINARY DISCOURSE.

PHYSIOLOGY* is the science of life. The term life is applied to an aggregate of phenomena, which manifest themselves in succession, for a limited time in organized bodies. Combustion is likewise only a combination of phenomena; oxygen unites with the substance which is burning, caloric is disengaged from it; affinity is the cause of these chemical phenomena, as attraction is the cause of the phenomena of Astronomy, and in the same manner as the sensibility and contractility of living and organized bodies are the primary causes of all the phenomena which such bodies exhibit—phenomena, which in their union and aggregate succession constitute life.

The false notions which have been entertained on the subject of life, and the vague definitions which have been given of it, are to be accounted for, by considering that physiologists, instead of regarding life as a simple result, have mistaken it for the properties of life. These last are causes; the first is merely an effect, more or less complex; and, as the spring of a watch, or rather the elasticity of that spring, determines by the mere action of the wheels, the motion of the hands and all the phenomena of which the machine is capable; so the vital properties acting by the organs produce all those effects, which in their combination constitute life. These effects are more or less numerous, according to the number of the organs; they become more rapid too in their succession and life more active, with the increase of energy in the vital properties. Precisely as the motions of a watch become more complicated, stronger or quicker, according to the greater tension of the spring, or the increased number of the wheels. Sensibility and contractility, are to be ranked among primary causes, of whose existence and laws we acquire a knowledge from observation, but whose essence eludes our investigation,* and will probably remain for ever beyond its reach.

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* Anatomy is *the science of organization.*

§ I. OF NATURAL BEINGS.

The vast domain of nature is divided between two classes of beings. *Inorganic* beings, possessing merely the common properties of matter; *organic* and *living* beings, obeying particular laws, though subjected to the general laws which regulate the universe. Each of these two grand divisions is naturally divided into two classes; we meet with inorganic bodies under the form of *elementary substances*, simple and not capable of analysis; or else under the form of *mixed* substances, compound, and admitting of decomposition. Thus, too, organized beings exist under two very different forms of life, which distinguish them into vegetables and animals.

The first general conception with which we ought to enter upon this comprehensive study of nature, is the mutual dependence of those beings, which, in their co-ordinate whole, compose the system of nature; a dependence which requires for each the simultaneous existence of all. Thus a vegetable derives its nourishment from inorganic bodies, and alters their inert substance, which is unfit for the food of animals, unless it has previously undergone the influence of vegetable life.

§ II. OF THE ELEMENTS OF BODIES.

Another consideration, of equal importance with the former, is the convertibility of all those substances so different from one another, and their capacity of being reduced to a small number of simple substances, called *elements*. The ancient doctrine of Aristotle, relative to the four elements, still prevailed in the schools, with a few modifications, which it had received from the chemists, when the "Pneumatists†" demonstrated by their beautiful experiments, that three, at least, of these pretended principles of bodies, air, water and earth, far from being simple substances, were evidently formed by the union and combination of several others; that atmospherical air, for example, far from being an homogeneous fluid, was composed of many different gases, and that in its purest state, it contains at least two very distinct principles, oxygen and azote; that water is a compound of oxygen and hydrogen, and that earth contains clay, lime, silex, &c.

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* It would be wrong to infer, from our ignorance of the nature of the vital properties, that physiology is an uncertain Science. Its certainty in that point of view, is equal to that of other parts of natural philosophy. The chemist, who explains all his combinations by referring them to the principle of affinity, and the astronomer, who finds in attraction the cause that rules the universe, are absolutely ignorant of the nature of those properties.

† This is the name given to the school of modern chemistry, because it originated from the discoveries made relative to the nature of air and elastic fluids. It must be acknowledged, to the credit of metaphysics, that the old errors were

We have seen added in the present day, to the number of the elements or simple substances, several which were not considered as such, at the time when natural philosophers, misled by erroneous metaphysical doctrines, had created out of their imaginations, beings of the existence of which they could find no proof. There is every reason to believe, that the number of substances not admitting of decomposition, limited at present to forty four, may hereafter be increased or diminished, by the discovery of new principles in simple substances, or of new elements in compound bodies, which have hitherto eluded the investigation of chemists. Whatever may be the success of their enquiries, of which it is impossible to foresee the results, or to fix the limits, there is reason to believe, that it will ever be denied us, to arrive at a knowledge of the true elements of bodies, and that many of those substances, which the imperfection of our means of decomposition or analysis obliges us to consider as such, are frequently compound substances and subject to their laws.

After what has been stated on the elements or constituent principles of substances, let us now see in what manner the combination of these elements gives existence to all beings, and what are the general differences existing among the great classes into which they are divided.

§ III. DIFFERENCES BETWEEN ORGANIZED AND INORGANIZED BODIES.

Much attention has been bestowed of late, on the difference which exists between organized and inorganized bodies. The latter have been observed to be very different from those which are en-

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forsaken, only at the period when chemists were thoroughly convinced of this truth, that every idea is obtained through the medium of the senses and that nothing is to be admitted beyond what they demonstrate in actual experiment.

dowed with life, in the homogeneous nature of their substance, in the complete independence of their molecules, each of which, according to the observation of Kant, has in itself causes to account for its peculiar mode of existence, in that power of resisting decomposition which they owe to the simplicity of their structure, and in the absence of those peculiar powers which free organic bodies from the absolute dominion of physical laws. The multiplicity, the volatility of their elements, the necessary union of fluids and solids, the nutrition and developement from the diffusive combination, while the growth of inanimate bodies takes place from the mere juxta position of particles, the origin of living bodies in generation, their destruction in death, such are the characters which distinguish organized beings from inorganized substances. We are about to enter into a detail of those characters, to appreciate all their differences, for knowledge is to be acquired only by comparison; and the greater our accuracy in comparing, the more precise and extensive will be the knowledge we obtain. Several modern authors have proved, that it is impossible to obtain an accurate idea of life, except by comparing those bodies which are endowed with it, with those in which life has never existed, or has ceased to exist. This comparison, I hope, will be fruitful in interesting results, and will furnish several useful considerations, immediately applicable to the knowledge of man.

The first remarkable difference between organized and inorganized bodies, is to be found in the homogeneousness of the latter, and the compound nature of the former. Let a block of marble be broken, each piece will be perfectly similar to the rest, there will be no differences among them, but such as relate to size or shape. Break down the fragments, each grain will contain particles of carbonate of lime, which will be throughout the same. On the other hand, the division of a vegetable or an animal, shews parts heterogeneous or dissimilar. In different parts there will be found muscles, bones, arteries, blossoms, leaves, bark, pith, &c.

Organized beings cannot live, or exist in their natural condition, unless solids and liquids enter at once into their composition. The co-existence of these two elements is necessary; and living bodies always contain a liquid mass more or less considerable, and incessantly agitated by the motion of the solid and living parts. It is in fact impossible to conceive life existing, without a complicated combination of solids and fluids; and without admitting in the former, the faculty of being affected by impressions from the latter, and the power of acting in consequence of those impressions. The water which penetrates into mineral substances, does not form a necessary part of them, and one cannot adduce in proof of the existence of liquids in that class of substances, the water of crystallization, though intimately combined, and rendered solid in the crystallized substances.

These inorganic and homogeneous substances, formed of particles similar to one another, when resolved by decomposition into their last elements, possess a great simplicity of inward nature. Among them are ranked all the substances which do not admit of analysis; the mineral compounds are often binary, as the greater part of saline substances; sometimes they are ternary, but seldom quaternary; while the most simple vegetable contains at least three constituent principles, oxygen, hydrogen and carbon, and no being possessed of life, consists of less than four, oxygen, hydrogen, carbon and azote. In the degree of composition, nature appears therefore to rise in gradations, from the mineral to the vegetable, and from the latter to the animal kingdom. The complicated nature of the latter, the multiplicity of their elements account for their tendency to alteration. Minerals are not subject to change, unless they are acted upon by external causes. Endowed with a vis inertiæ, they continue in one condition without change. The state of organized bodies is incessantly varying. Their internal parts contain an active laboratory, in which a number of instruments are constantly transforming into their own substance, nutritious particles. Besides that tendency to alteration in living animals and vegetables, when deprived of life, they become decomposed, by a process of fermentation, which begins in their internal parts, and by which their nature is changed in proportion to the complication of their structure, and the greater number and volatility of their constituent principles.

All the parts of a living body, whether of an animal or a vegetable, have a natural tendency to a common object, the preservation of the individual and of the species; each of the organs, though provided for a peculiar action, concurs in this object; and life in general, or life properly so called, is the result of that series of concurring and harmonic actions. On the contrary, each part of an inorganic mass, is independent of the other parts, to which it is united, only by the force or affinity of aggregation. When such a part is separated from the rest, it maintains all its characteristic properties, and differs only by its size, from the mass to which it no longer belongs.

Among animals and vegetables, all the individuals of the same class, appear to have been formed after the same model; their parts are equal in number, and resemble each other in colour; their differences are slight and evanescent. The forms peculiar to organized beings are therefore invariably determined, and when nature departs from them, she never does so, to such a degree, as in the shapes of minerals. The veins of mines are never precisely alike, as the leaves of vegetables or the limbs of animals. Crystals formed from similar substances, assume very different shapes equally distinct and precise. Carbonate of lime, for example, assumes according to circumstances the shape of a rhomboid, that of a six sided regular prism, that of a solid, terminated by twelve scaleni triangles, that of a different dodecahedron with pentagonal faces, &c. as may be seen at large in the writings of Haüy.

A powerful inward cause, seems to arrange the constituent parts of animal and vegetable bodies, by a determinate rule, in such a manner that they shall present a surface, more or less completely rounded. Minerals often take their form, from external bodies, and when an especial force assigns it to them, as in crystals, their surfaces are flat and angular. When the crystallization is disturbed, and the molecules of the crystals are driven tumultuously together, the geometrical form is impaired, the parts are rounded, which would have been terminated by angles, if a slow and tranquil crystallization had allowed of regular aggregation: and as M. Haüy has remarked, these waving outlines, these roundings, so frequent in vegetables and plants, where they belong to beauty of form, are, in minerals, indication of defects. True beauty, in these beings, is characterized by the straight line, and it is on good grounds that Romè de Lisle* has said of this sort of line, that it seems to have an especial determination to the mineral kingdom.

Amongst all the characteristics which distinguish the two great divisions of natural bodies, the most absolute, and the most palpable, is that which is drawn from the manner of growth and of nourishment. Inorganic bodies grow only by accretion, that is, by the accession of new layers to their surface, whilst the organic, in virtue of its vital powers, receives into intimate combination, and is penetrated and pervaded, by the substance it assimilates to itself. In animals and plants, nutrition is the effect of an internal mechanism: their growth, is a developement from within. In minerals, on the contrary, growth cannot claim the name of developement: it goes on externally, by successive addition of new layers; it is the same being, assuming other dimensions, whilst the organic body is renewed in its growth.

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* Cristallographie, Tom. I. p. 94.

Living bodies spring from a germ, which at first, was part of another being, from which it detaches itself, for the sake of its own developement and growth. From the first, they are already aggregates. Inorganic bodies have no germ: they are made up of distinct parts brought together; they have no birth, but a multitude of molecules, collecting into one, compose masses of various bulk and figure.

Organized bodies alone can die; all have a duration, determined by their own nature; and this duration is not like that of minerals, proportioned to the bulk and density: for, if man has not the life of the oak, whose substance much exceeds his in density, neither does he equal the life of many animals, such as fishes, whose flesh is of inferior consistence to his own: and he lives longer than the large quadrupeds, though his bulk is less.

Finally, inorganic are essentially distinguished from organic bodies, by the want of these peculiar powers or properties of living nature; powers, which uphold the equilibrium of the whole system of nature, as I shall explain more at large, when I have considered the differences that mark the two divisions of the organic kingdom, vegetables and animals.

§ IV. DIFFERENCES BETWEEN VEGETABLES AND ANIMALS.

These are much fewer, less absolute, and therefore more difficult to establish. There is, in fact, very little difference between a zoophyte, and a plant, and there is a much wider distance in their internal œconomy, between man, who stands at the height of the animal scale, and the polypus on its lowest line, than between the polypus and a plant. There lies between organized and inorganic bodies, a space, which is not to be filled up by figured stones, nor by lithophytes, nor by crystals, in which some naturalists have thought, they saw a beginning of organization. Whilst, at the extremity of the animal chain, are found beings, fixed, like plants, on the spot of their birth, sensitive and contractile, like the sensitive and some other plants, and reproduced like them from slips. Yet we are able to state some differences, sufficiently marked, to assign to the vegetable kind, a character of their own, which will not suit the individuals of either of the other kingdoms.

Their nature, more complex than that of minerals, is less so than that of animals: the proportion of the solids to the liquids, is greater than in these last: accordingly they retain, long after death, their form and bulk, only that they grow lighter. The solids are, in man, nearly a sixth of the whole body: his carcase, decomposed by putrefaction, remains a little earth, and a light skeleton, when the ground and the air have drawn from it all its juices. A tree, on the contrary, is more than three parts of its substance, solid wood. It has been dead for ages, and yet, in our buildings, it preserves its form and size, though by drying, it has lost a little of its weight.

Their constituent principles, as they are less in number, are also less diffusible. In fact, azote, which is predominant in animal substances, is a gaseous, and volatile principle, whilst carbon, the base of vegetable substance, is fixed and solid. This circumstance, added to the smaller quantity of their liquids, explains the long duration after death, of vegetable substances.

But of all the characteristics which have been employed in establishing the limits of animal and vegetable nature, there is one quite sufficient to distinguish these two great classes of beings, but which has not yet been allowed the weight it deserves.

The zoophyte, who, fixed in his rocky habitation, cannot change his place, confined to partial movements, which certain plants are possessed of, who besides, has not that sensitive unity, so remarkable in man, and in the animals, who nearest resemble him in their organization; the zoophyte, whose name indicates an animal-plant, is totally separated from all beings of the vegetable kingdom, by the existence of a cavity, in which alimentary digestion is carried on, a cavity by the surface of which is an absorption, an *imbibition*, far more active than that which takes place by the external surface of the body. From this shapeless animal, up to man, nutrition is effected by two surfaces, and especially the internal, whilst in the plant, nutrition, or rather the absorption of nutritive principles, is only by the external surface.

Every animal may be considered, in extreme abstraction, as a nutritive tube, open at the extremities* ; the whole existence of the polypus seems reduced to the act of nutrition, as its whole substance is employed in the formation of an alimentary tube, of which the soft parietes, extremely sensible and contractile, are busied in appropriating to themselves, by a sort of absorption, the substances which are brought into it. From the worm up to man, the alimentary canal is a long tube, open at the extremities ; at first, only of the length of the body of the animal, not bent at all in passing from the head to the tail, and carried on towards the mouth, and towards the anus, with the external covering of the body, but soon returning upon itself, and stretching out into length, far beyond that of the body which contains it.

It is in the thickness of the parietes of this animated tube, betwixt the mucous membrane that lines it inwardly, and the skin with which this membrane is continuous, that all the organs are placed, which serve for the transmission and elaboration of fluids, together with the nerves, the muscles, in short, all that serves for the carrying on of life. As we rise, from the white-blooded animals, to the red- and cold-blooded, from these to the warm-blooded, and from these to man, we see a progressive multiplication of the organs that are contained within the thickness of the parietes of the canal :—If we follow, on the other hand, the descending scale, we see this structure gradually simplified, till we arrive at last at the polypus, and find in it only the essential part of animal existence. The simplicity of its organization is such, that it may be turned inside out, and the external be made the internal surface ; the phenomena of nutrition, which are the whole life of the animal, go on, from the close analogy between the two surfaces ; unlike to man and the greater part of animals, in whom the skin and the mucous membranes, though growing into each other, though linked by close sympathies, are far from possessing a complete analogy of structure, or a capacity for the interchange of functions.

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* *Lacépéde*, Histoire Naturelle des Poissons, tom. 1. There may be brought, against this principle, the instance of some zoophytes, such as spunges, &c. ; but do these bodies really belong to the animal kingdom ? and should not we be warranted in rejecting them, by the want of the alimentary cavity, the essential characteristic of animal existence ?

Man, then, and the whole animal kind carry about within themselves, the supply of their subsistence; and absorption, by an inward surface, is their distinguishing characteristic. It is inaccurate to ascribe to Boerhaave the comparison of the digestive system of animals, to the soil in which plants suck up the juices that feed them, and the chylous vessels, to real internal roots. I find the same thought well expressed in the work on humours, which, justly or falsely, bears the name of Hippocrates. *Quemadmodum terræ arboribus, ita animalibus ventriculus.*

The digestive tube, that essential part of every animal, is the part of which the existence and action are the most independent of the concurrence of the other organs, and to which the properties of life seem to adhere, if one may say so, with most force. Haller,* who has made so many and such interesting enquiries into the contractile power of the muscular organs, examining them under the two-fold relation of their irritability, as it is more or less lively, or more or less lasting, looks on the heart, as the one in which these two conditions are found in the highest combination. He gives the second place to the intestines, the stomach, the bladder, the uterus, and the diaphragm, and, after these, all the muscles under the command of the will. I had at first admitted, with every other writer, this classification of the contractile parts; but more than a hundred experiments on living animals have satisfied me, that the intestines are always the last part in which the traces of life may be discovered. Whatever may be the sort of death by which they are destroyed, peristaltic motions, undulations, are still continued in this canal, while the heart has already ceased to beat, and the rest of the body is all an inanimate mass. M. Jurine had already observed on the pulex monoculus, that, of all the parts of the body of this little white-blooded animal, the intestines were the last to die.

If the intestinal tube be the *ultimum moriens*, if it be the last organ in which life lingers and goes out, it is to it we ought to direct, in preference, the stimulants that are capable of recalling it in case of asphyxia. I think that, after the blowing of pure air into the lungs, the means that ought next to be attended to, is the injection of acrid and irritating clysters, thrown in with force. The large intestines are connected with the diaphragm by a close sympathy, as is proved by the phenomena of fecal evacuation: the irritation of them is the surest means of accelerating it; and this irritation is the easier, as the alimentary canal is the last part that is forsaken by life.

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* *Opera minora*, 3 vol. 4to.

§ V. OF LIFE.

After having thus laid down, between inorganic bodies and organized living beings, and again between animal and vegetable nature, a line of demarcation that cannot be mistaken, let us endeavour to exalt ourselves to the conception of Life; and, for accuracy of thought, let us, in some sort, analyse it, by studying it in all the beings of nature that are endowed with it. In this study, of which I may be allowed to state, in advance, the results, we shall see life composed at first of a small number of phenomena, simple as the apparatus to which it is given in charge; but soon extending itself as its organs or instruments are multiplied, and as the whole organic machines become more complex; the properties which characterize it and bear witness of its presence, at first obscure, becoming more and more manifest, encreasing in number as in developement and energy; the field of existence enlarging, as from the lower beings we re-ascend to man, who, of all, is the most perfect: and observe, that by this term of perfection, it is simply meant that the living beings to which we apply it, possessed of more means, present also more numerous results and multiply the acts of their existence; for in this wonderful order of the universe, every being is perfect in itself, each being is constructed most favourably for the purpose it is to fulfil; and all is equally admirable, in living and animated nature, from the lowest vegetation to the sublimity of thought.

What does this plant present to us that springs up, and grows, and dies every year? A being whose existence is limited to the phenomena of nutrition and reproduction; a machine constructed of a multitude of vessels, straight or winding, capillary tubes, through which the sap is filtrated and other juices necessary to vegetation; these vegetable liquors ascend, generally, from the roots, where their materials are taken in, to the summit, where what remains from nutrition is evaporated by the leaves, and what the plant could not assimilate to itself is thrown off in transudation. Two properties direct the action of this small number of functions: a latent and faint sensibility, in virtue of which, each vessel, every part of the plant, is affected in its own way by the fluids with which it is in contact: a contractility as little apparent, though the results prove irrefragably its existence; a contractility, in virtue of which, the vessels, sensible to the impression of liquids, close or dilate themselves, to effect their transmission and elaboration. The organs allotted to reproduction, animate, for a moment, this exhibition: more sensible, more irritable, they are visibly in action; the stamina, or male organs, bow themselves over the female organ, the pistil, shake on the stigma their fertilizing dust, then straighten, retire from it, and die with the flower, which is succeeded by the seed or fruit.

This plant, divided into many parts, which are set in the earth with suitable precautions, is reproduced and multiplied by slips, which proves that these parts are little enough dependent on each other; that each of them contains the set of organs necessary to life, and can exist alone. The different parts of a plant can live separately, because life, its simpler organs and properties are diffused more equably, more uniformly, than in animals like man, and its phenomena are connected in a less strict and absolute dependance. I myself have witnessed a very curious fact, which confirms what I have said.* A vine, trained against the eastern wall of a forge, shot into the building a few branches. These branches, which entered by strait enough passages, were covered with leaves in the middle of the hardest winters; and this premature but partial vegetation went through all its periods, and was already in flower, when the part that remained without, was beginning to bud with the spring.

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* Vegetable life compared in its means and in its results, to the life of animals, would throw the greatest light on many phenomena which it is still difficult for us to conceive and to explain. The treatment of disease in plants, for which as much would be gained by these enquiries, is almost entirely surgical. When, to make vegetation more fruitful, the gardener prunes a luxuriant branch; when the peasants of the Cevennes, as M. Chaptal has observed, burn the inside of their chesnut trees to stop the progress of a destructive caries; when the actual cautery is applied to the really ichorous and foul ulcers of many trees, &c. it is to the organs of inward life, (or that which carries on the process of assimilation,) the only life of vegetables, that surgery is applied; while, on the contrary, in man and animals, it is to the derangement of the external organs that the remedy is directed. I shall conclude this note with an observation on the wounds of plants. Like those of the human body, they are much less dangerous when their surface is smooth, than when their edges are hacked, torn, or bruised. Trees felled with the saw, will hardly shoot up from the stool, which always furnishes a better growth when an axe has been employed. The saw lacerates the vegetable texture, and its violent and

If we pass from the plant to the polypus, which forms the last link of the animal chain, we find a tube of soft substance, sensible and contractile in all its parts, a life and an organization at least as simple as that of the plant. The vessels which carry the liquids, the contractile fibres, the *tracheæ*, which give access to the atmospheric air, are no longer distinctly to be traced in this almost homogeneous substance. There is no organ especially allotted to the reproduction of the kind. Moisture oozes from the internal surface of the tube, softens and digests the aliments which it finds there; the whole mass draws in nourishment from it; the tube then spontaneously contracts, and casts out the residue of digestion. The mutual independence of parts is absolute and perfect: cut the creature into many pieces, it is reproduced in every piece; for each becomes a new polypus, organized and living, like that to which it originally belonged. These *gemmiparous* animals enjoy, in a higher degree than plants, the faculties of feeling and of self-motion; their substance dilates and lengthens, and contracts, according to the impressions they receive. Nevertheless, these spontaneous movements do not suppose, any more than those of the mimosa, the existence of reflexion and will: like those of a muscle detached from the thigh of a frog and exposed to galvanic excitation, they spring from an impression which does not extend beyond the part that feels it, and in which sensibility and contractility are blended and lost in each other.

From this first degree of the animal scale, let us now ascend to worms. We have no longer a mere animated pulp shaped into an alimentary tube; parcels of contractile or muscular fibres, a vessel divided by several constrictions into a series of vesicles,

distressing action on the fibres, extending towards the roots, affects, more or less, the organization. The uneven surface of a tree felled in this manner, holds wet, as injurious to the trunk, which it rots, as a too great quantity of pus, which bathes constantly the surface of a wound, checks the process of granulation, and resists cicatrization.

which empty themselves one into another, by a movement of contraction that begins from the head, or the entrance of the alimentary canal, and proceeds towards the tail, which answers to the anus, a vessel, from which, in all probability, are sent out lateral ramifications, a spinal marrow equally knotted, or composed of a chain of ganglions, stigmas, and tracheæ, analogous to the respiratory organs of plants, and in some, even gills: all shews clearly an organization further advanced and more perfect; sensibility and contractility are more distinct; the motions are no longer absolutely automatic; there are some which seem to suppose choice. The worm too, may be divided into many pieces; each will become a separate and perfect worm, a head and tail growing to each; but this division has its term, beyond which there is no longer complete regeneration. It cannot, therefore, be pushed so far as in the polypi. The substance of the worm being formed of elements more dissimilar, it may be that too small a portion does not contain all that is necessary to constitute the animal.

The crustaceous tribes, and among them the lobster, discovers a more complex apparatus of organization. Here you will find distinct muscles, an external articulated skeleton, of which the separate parts are moveable upon each other, distinct nerves, a spinal marrow with bulgings, but, above all, a brain and a heart. These two organs, though imperfect, assign the animal to an order much above that of worms. The first becomes the seat of a sort of intelligence; and the lobster acts evidently under impulses of will, when, attracted by a smell, it pursues a distant prey, or when it flies a danger discovered to it by its eyes. There are viscera accompanying the intestinal tube, which give out to it liquids that concur in alimentary digestion. Sensibility and contractility present each two shades: in fact, the parts of the animal are obedient to the internal stimuli, feel the impression of fluids, and contract to impel them; on the other hand, by its nerves and locomotive muscles, the lobster places itself in connexion with the objects that surround it. The phenomena of life are linked together by a strict necessity: it is no longer possible to separate the creature into two parts, of which each may continue to live; there are but few parts you may cut off without injury, while you spare the central foci of life. So, if you take off a claw, you observe soon a little granulation, which swells and is developed, and which, soft at first, is soon clothed in a calcareous covering, like that which encloses the rest of its body. This partial regeneration is frequently to be seen.

If from white-blooded animals we go on to the red- and cold-blooded, such as fishes and reptiles, we see this power of reproduction becoming more and more limited, and life more involved in organization. In fact, if you cut off a part of the body of a fish, the tail of a serpent, or the foot of a frog, the separated parts are either not supplied at all, or very imperfectly reproduced. All these creatures maintain, with the medium in which they live, relations of more strict dependence. Gills in these, lungs in others, are added to a heart, nor are less essential to life. However, the action of these chief organs is not so frequent, nor of momentary necessity for the continuance of life. The serpent passes long winters, torpid with cold, in holes where he has no air, without breathing, without any motion of life, and in all appearance dead. These creatures, like all reptiles, are able to breathe only at long intervals, and to suspend, for a time, the admission of air, without risking their existence. Here the vital powers are distinct and strong, and differ from those of the more perfect animals and of man, by very slight shades: the heart and the vessels of the fish feel and act within him, without his consciousness. Further, he has senses, nerves, and a brain, from which he has intimation of whatever can affect him; muscles and hard parts, by the action of which he moves, and changes his place, adapting himself to the relations that subsist between the substances around him and his own peculiar mode of existence.

We are come, at last, to the red- and warm-blooded animals, at the head of which are the mammiferæ and man. They are entirely alike, save some slight differences in the less essential organs. There is none that has not the vertebral column, four limbs, a brain which fills, exactly, the cavity of the skull, a spinal marrow, nerves of two sorts, five senses, muscles, partly obedient to the will, partly independent in their action; add to these, a long digestive tube coiled upon itself, furnished at its mouth with agents of saliva and mastication; vessels and lymphatic glands, arteries and veins, a heart with two auricles, and two ventricles, lobular lungs, which must act incessantly in impregnating the blood, that passes through them, with the vital part of the atmosphere, which, if it fail, life is suspended, or gone. None of their organs live but while they partake in the general action of the system, and while they are under the influence of the heart. All die, irrecoverably, when they are parted from the body of the animal, and are in no way replaced; whatever some physiologists may have said on pretended regeneration of the nerves, and some other parts.

Every thing that is important to life, is to be found in these animals; and as the most essential organs are within, and concealed in deep cavities, a celebrated naturalist was correct in saying, that all animals are essentially the same, and that their differences are in their external parts, and chiefly to be observed in their coverings and in their extremities.

The human body, consisting of a collection of liquids and solids, contains of the former, about five-sixths of its weight. This proportion of the liquids to the solids may, at first sight, appear to you beyond the truth: but consider the excessive decrease of size of a dried limb: the glutæus maximus, for example, becomes, by drying, no thicker than a sheet of paper. The liquids, which constitute the greatest weight of the body, exist before the solids: for, the embryo which is at first in a gelatinous state, may be considered as fluid; besides, it is from a liquid that all the organs receive their nourishment and repair their waste. The solids, formed from the liquids, return to their former state, when, having for a sufficient length of time, formed a part of the animal, they become decomposed by the nutritive process. Even from this slight view of the subject, fluidity is seen to be essential to living matter, since the solids are uniformly formed from the fluids, and eventually return to their former state. Solidity is then only a transient condition and an accidental state of organized and living matter, and this circumstance affords to the humoral pathologists ample opportunities of embarrassing their opponents with many objections, not easily answered. Water forms the principal part and the common vehicle of all the animal fluids, it contains saline substances in a state of solution, and even animal matter itself is found in it fluid, and that in three different conditions, under the form of *gelatine*, of *albumine*, or *fibrine.* The first of these substances, solidified, forms the basis of all the organs of a white colour, to which the ancients gave the name of spermatic organs, such as the tendons, the aponeurosis, the cellular tissue, and the membranes. Albumine exists in abundance in almost all the humours; the fibrine of the blood is the cement which is employed in repairing the waste of a system of organs, which, in point of bulk, hold the first rank among the constituent parts of the human body—I mean the muscular system. The chemists suspect, and not without reason, that the animal matter passes successively through the different states of gelatine, albumine and fibrine; that these different changes depend on the progressive animalization of the animal matter, which, at first gelatinous, a hydro-carbonous oxyde, containing no azote, and acidifiable by fermentation, becomes more closely combined with oxygen, takes up azote, so as to become albumen, subject to putrefaction, and finally fibrine, by a super-addition of the same principles.

The solid parts are formed into different systems, to each of which is intrusted the exercise of a function of a certain degree of importance. Limiting the term organic apparatus, or system, to a combination of parts which concur in the same uses, we reckon ten, viz.—the *digestive* apparatus, consisting essentially of the canal which extends from the mouth to the anus; the *absorbent*, or lymphatic system, which is formed of the vessels or glands of that name; the *circulatory* system, which consists of an union of the heart, the veins, the arteries and the capillary vessels; the *respiratory*, or pulmonary system; the glandular, or *secretory* system; the *sensitive* system, including the organs of sense, the brain and spinal marrow; the *muscular* system, or that of motion, including not only the muscles, but their tendons and aponeuroses; the *osseous* system, including the appendages of the bones, the cartilages, the ligaments and the synovial capsules; the *vocal* system, and the *sexual*, or *generative* system, different in the two sexes. Each of these organic systems contains in its structure several simple tissues, "or similar parts," as the ancients called them;—these tissues in man, may be enumerated as follows: *cellular tissue*, *nervous tissue*, *muscular tissue*, besides that *horny substance* which constitutes the basis of the epidermis, the nails and the hair.

These four substances may be considered as real organic elements, since with our means of analysis, we never can succeed in converting any one of these substances into another. The cerebral pulp is not convertible into a horny substance, into cellular substance, or into muscular fibre, neither can any one of these tissues ever be converted into cerebral pulp. The bones, the cartilages, the ligaments, the tendons, the aponeuroses, may, by long maceration, be decomposed into cellular substance.

Muscular fibres are not subject to that alteration, nor is the nervous or cerebral pulp; the horny substance also resists that change. Every thing, therefore, leads us to acknowledge these four constituent principles in our organs.

The primitive or simple tissues, variously modified, and combined in different quantities, and in various proportions, constitute the substance of our organs. Their number is much more considerable, according to Bichat, whose happiest conception was this analysis of the human organization. This physiologist reckoned in the human œconomy, no fewer than twenty-one general or generating tissues. But it is evident, that this analysis is carried too far; that the tissues of which the skin and the hair are formed, are exactly of the same nature, are analogous in their properties, and are nourished in a similar manner; that the cellular tissue is the common basis of the osseous, cartilaginous, mucous, serous, synovial, dermoid, &c.

It must be confessed, that this separate consideration of each organic tissue has furnished him with new ideas, ingenious analogies and useful results, and that his "Anatomie generale," in which those researches are contained, is his chief title to glory. That glory would be complete, if in that book, and yet more, in his other works, he had done his predecessors, as well as his contemporaries, the justice they had a right to expect from him.

The simple, or elementary fibre, about which so much has been written, may be considered as the philosopher's stone of physiologists. In vain, has Haller himself, in his pursuit of his chimera, told us, that the elementary fibre is to the physiologist what the line is to the geometer, and, that as all figures are formed from the latter, so are all the tissues formed from this fibre; *Fibra enim physiologo id est quod linea geometræ, ex qua nempe figuræ omnes oriuntur.* The mathematical line is imaginary, and a mere abstraction of the mind, while the elementary fibre is allowed a material or physical existence. Nothing, therefore, can make us admit the existence of a simple, elementary, or primitive fibre, since our senses shew us, in the human organization, four very distinct materials.

Among the organs, whether single or combined in systems, which enter into the human organization, there are some whose action is so essential to life, that, with the cessation of that action, life at once becomes extinct. These primary systems, whose action regulates that of all secondary systems, are as numerous in man as in the other warm-blooded animals. None of them can act, unless the heart sends into the brain a certain quantity of blood, vivified by the contact of atmospherical air in the pulmonary tissue. Every serious wound of the brain or heart, every lasting interruption to the access of blood into the former of these organs, is invariably attended with death. The oxydation of the blood, and its distribution into all the organs, is consequently the principal phenomenon, on which the life of man and of the most perfect beings depend.

§ VI. OF THE VITAL PROPERTIES; SENSIBILITY AND CONTRACTILITY.

By sensibility is meant that faculty of living organs, which renders them capable of receiving from the contact of other bodies, an impression stronger, or fainter, that alters the order of their motions, increases or diminishes their activity, suspends, or directs them. Contractility is that other property by which parts excited, that is, in which sensibility has been called into action, contract or dilate, in a word, act, and execute motions. In the same manner, as we have not always a consciousness of the impressions received by our organs, and as, for example, no sensation informs us of the stimulating impression by which the blood calls the heart into action, so it is by reflexion only, that we are induced to admit the existence of certain motions; of those, for instance, by which the humours, when they have reached the smallest vessels, become incorporated into the tissue of our organs. These motions, to make use of an ingenious comparison, resemble those of the hour-hand, compared with the second-hand of a watch. The hour hand appears motionless, and yet in twelve hours it describes the whole circumference of the dial plate, round which the other hand moves in one minute, with a motion that is visible.

In considering life through the great series of beings that possess it, we have seen that those in which it is most limited, or rather in which it consists of the least number of actions and phenomena, vegetables, for instance, and animals like the polypus, which have no brain, no distinct nervous system, are at once endowed with sensibility and contractility in all their parts. All living beings, all the organs which enter into their composition, are impregnated, if we may be allowed the expression, with these two faculties, necessarily co-existing, and which shew themselves by internal and nutritive motions, obscure, indeed, and to be distinguished only by their effects. These two faculties appear to exist in the degree absolutely required for enabling the fluids that pervade all the parts of a living body, to induce the action by which these parts are to assimilate such fluids. It is clear, that the two properties of feeling and of motion are indispensable to all parts of the body. They are properties universally diffused through organized and living matter, but they exist without possessing any peculiar organ or instrument of action. Were it not for these two faculties, how would the different parts act on the blood, or on the fluid which supplies its place, so as to obtain from it the materials subservient to nutrition and the different secretions? These faculties are therefore given to every thing that has life—to animals, to vegetables, to man in his waking hours, or in his most profound sleep, to the fœtus, to the child that is born, to the organs of the assimilating functions, and to those which connect us with surrounding beings. Both these faculties, obscure, and inseparable, preside over the circulation of the blood, of the fluids, and, in short, over all the phenomena of nutrition.

Though this kind of sensibility is always latent or concealed, it is otherwise with regard to contractility, which may be sensible or otherwise. The bone, which takes up the phosphate of lime, to which it owes its solidity, exerts that action without our being aware of its taking place, except by its effect: but the heart which feels the presence of the blood, without any consciousness, on our part, of such sensation, exerts motions that are easily perceptible, but over which we have no controul, either to suspend or accelerate them.

Vital properties in so weak a degree, would not have been sufficient to the existence of man and of the animals which resemble him, obliged to keep up multifarious intercourse with every thing that surrounds them; thus they enjoy a very superior kind of sensibility, by means of which the impressions which affect some of their organs are perceived, judged and compared. This mode of sensibility might be more properly called *perceptibility*, or the faculty of accounting to oneself for the emotions which are experienced. It requires a centre to which the impressions may be referred, and therefore it exists only in the animals which, like man, have a brain or some organ in its stead; so that the zoophytes and vegetables, wanting that organ, are equally destitute of this faculty. The polypi, and some plants, as the sensitive, perform nevertheless certain spontaneous motions, which seem to indicate the existence of volition, and consequently of perceptibility. But these motions are the result of an impression, which does not extend beyond the part in which it is experienced, and in which sensibility and contractility are blended.

The almost latent sensibility of certain parts of the body, cannot be absolutely compared to that of vegetables; since those organs whose sensibility is so imperfect, manifest in disease a *percipient* sensibility, which shews itself by acute pain, and it is even sufficient to change the stimulus to which they are accustomed, to determine the occurrence of that phenomenon. Thus the stomach, on the parietes of which, the food does not in health produce any perceptible impression, becomes the seat of very distinct sensation and of dreadful pain, when a small quantity of poisonous matter is introduced into it. In like manner, we are not conscious of the impressions excited in the parietes of the bladder or rectum, by the collection of urine or fœcal substances, except when their contents have become sufficiently irritating by their presence, to excite, in a certain degree, those irritable and sensient cavities, and to transform their obscure, into a very distinct sensibility. Is there not reason to suspect, that our unconsciousness, in health, of the impressions made on our organs by the fluids which they contain, depends on our being accustomed to the sensations which they incessantly excite? so that there remains but a confused perception, which in time disappears, and may we not, under that point of view, compare all these organs to those of sight, hearing, smelling, tasting, and touching, that are no longer irritable by stimulants, to which they have long been habituated?

Two systems of organs, very different in their uses and in their qualities, enter into the composition of the human body; they are as two living and united machines, the one, formed by the organs of sense, the nerves, the brain, the muscles, and the bones, serves to maintain its connexion with external objects; the other, destined to internal life, consists in the digestive tube, and the organs of absorption, circulation, respiration, and secretion. The organs of generation in the two sexes form a separate class, which, as far as relates to the vital properties, partakes of the nature of the other two.

By the organs of sense, and the nerves which form a communication between these organs and the brain, we are enabled to perceive or to feel the impressions made on us by external objects; the brain, the true seat of that *relative* sensibility, which might very justly be termed *perceptibility, or the perceptive power*, (Pott) when excited by these impressions, is able to irradiate into the muscles the principle of motion, and to induce the exertion of their *contractility.* This property, which is under the direction of the will, manifests itself by the sudden decurtation of a muscle, which swells, hardens, and determines the motion of those parts of the skeleton to which it is attached. The nerves and the brain are essentially the organs of these two properties, a division of the former is attended with a loss of sentiment and voluntary motion in the parts to which they are distributed. The other kind of sensibility is, on the contrary, quite independent of the presence of nerves; it exists in all organs, although all do not receive nervous filaments. It might even be asserted, that the cerebral nerves are not at all essential to the life of nutrition; the bones, the arteries, the cartilages, and several other tissues, in which no nerves are seen to enter, are nourished equally well with the organs in which they exist in considerable number; the muscles themselves will carry on their own internal œconomy, notwithstanding the division of their nerves; only, deprived of those means of communication with the brain, they can no longer receive from it the principle of voluntary contraction; instead of that sudden, energetic and lasting decurtation which the will determines in them, they become merely capable of those quiverings called palpitations.

The anatomist who studies the nerves, with a view to ascertain their termination, finds them all arising from the brain and spinal marrow, and proceeding, by a longer or shorter course, to the organs of motion or of sensation: let him take his scalpel and dissect one of our limbs, the thigh, for instance, he will see the cords parting into numerous threads, most of which disappear in the thickness of the muscles, whilst others, after creeping for a time about the cellular tissue, which joins the skin to the aponeurosis, end on the inward surface of the skin, of which they compose the texture, and expand into sentient papillæ on its surface. The bones, the cartilages, the ligaments, the arteries, and the veins; all those parts whose action is not under the controul of the will, are without them. Nevertheless, all those parts, which, in their natural state, send no perceptible impressions to the brain, which, when once insulated, may be tied and cut, without any sign of pain from the animal, and whose action the will does not controul, are yet endued with a sensibility and a contractility, which enable them, after their own manner, to feel and to act, to recognize in the fluids that moisten them, what is suited to their nourishment, and to separate that recrementitious part which has suitably affected their particular mode of sensibility.

In confining our attention then, to the consideration of a single limb, we may easily satisfy ourselves of the existence of two modes of feeling, as of two sorts of motion; a sensibility in virtue of which, certain parts can send up to the brain, the impressions they receive, to be there objects of consciousness; and another sensibility belonging to all organs without exception, and all that some of them possess, which is sufficient for the exercise of the functions of nutrition, and by means of which they are evolved, and are kept up in their natural state; two kinds of contractility, appropriated to the two different kinds of sensibility:—The one, in virtue of which the muscles obedient to the will, exercise the contractions which it determines; the other, independent of the will, manifests itself by actions, of which we have no intimation, any more than of the impressions by which they are determined.

The distinction being fairly laid down between sensibility and contractility, it is easy to understand the origin of the endless disputes of Haller and his followers, about the parts of the body, in man and animals, which are endowed with sensibility and irritability. All the organs to which that learned physiologist has denied these properties, as bones, tendons, membranes, cartilages, and cellular membrane, &c. possess only that latent sensibility, and that obscure contractility, common to all living beings, and without which, it is impossible to conceive life to exist. In a state of health, they are utterly incapable of transmitting to the brain perceptible impressions, and of receiving from it the principle of manifest and sensible motion. It has likewise been a matter of much dispute, whether sensibility and contractility are qualities of nerves; if these parts are their only instruments, and if their destruction is attended with a loss of these two vital properties, in the parts to which they are transmitted. We may answer in the affirmative, as far as relates to the sensibility of perception, and the voluntary motion which is entirely subservient to it, but that the existence of nerves is not at all necessary to the exercise of the sensibility and contractility which are indispensable to the assimilation of nutrition.

No part of the living body is absolutely insensible, but that sensibility of every organ is so modified, that it is not affected by the same stimuli. Thus, the eye is insensible to sound, and the ear to light. A solution of tartar emetic, causes no disagreeable impression to the conjunctiva; taken into the stomach, it excites convulsive motions, while an acid from which the stomach does not suffer, proves a cause of irritation to the conjunctiva, and brings on a violent inflammation of the eye. In the same manner, purgatives pass along the stomach, without producing any effect on that viscus, but they stimulate the alimentary canal. Cantharides have a specific action on the bladder; and mercury on the salivary glands. Each part feels, lives, moves, after its own way; in each, the vital properties appear under such shades and modifications, that they may be looked upon as so many separate members of the same family, concurring in one endeavour, working for a common end, *consentientia omnia* (Hipp.)

The faculty of assigning a cause to the sensations, and that of moving by volition, which man possesses in common with all animals formed with a distinct nervous centre, are essentially bound together. For suppose a living being, furnished with locomotive organs, but without sensation, placed in the midst of bodies, that every moment endanger its existence, without any means of distinguishing them, it will hasten its own destruction. If perceptibility could, on the other hand, exist independently of motion, how dreadful would be the fate of such sentient beings, similar to the fabulous Hamadryads, who, immoveably fixed in the trees of our forests, received, without any power to shun them, all the blows inflicted on their rustic abode. Dreams place us sometimes in situations which give us a just idea of their condition. A certain danger threatens our existence; an enormous rock seems to detach itself, to roll and precipitate itself on our frail machine; a frightful monster seems to pursue us, and opens a yawning mouth to ingulf us. We struggle to escape this imaginary danger, to avoid or to repel it, but an irresistible and unknown power, a mighty hand paralyses our efforts, and keeps us rooted to the spot; it is a situation of horror and despair, and we awaken overwhelmed with the uneasiness which we have suffered.

As there is no part that does not feel, in a manner peculiar to itself, so there is no one that does not act, move, or contract, in a manner peculiar to itself; and the parts which have been found without a power of motion analogous to muscular contractility, have remained in that state of immobility, only for want of a stimulus fitted to their peculiar nature. Some physiologists say they have excited a distinct quivering, in the mesentery of a frog and of a cat, by touching them, after they had been previously moistened with alcohol, or muriatic acid.

In the operation for sarcocele,* I have often perceived that, while with my left hand I supported the tumour, and with a scalpel in the right, divided the spermatic chord, the tunica vaginalis shewed oscillatory contractions. It visibly contracts in the operation for hydrocele. The injection of an irritating fluid determines evident motions in the tunica vaginalis. The osseous tissue, notwithstanding the phosphate of lime with which it is incrusted, is susceptible of a contraction, whose effects, though slow, are nevertheless undeniable. After teeth have been shed or extracted, the edges of the alveolar processes become thinned from contraction, and the alveolar cavities disappear. These facts appear to me to prove, still better than all the experiments performed on living animals, (experiments of which, by the bye, the results ought not too confidently to be applied to the œconomy of man) what one should think of the assertions of Haller and his followers, on the insensibility and inirritability of the serous membranes, and of the organs of a structure analogous to their's.

We will, at present, say nothing of the porosity, of the divisibility, of the elasticity, and other properties which are common to living bodies and inanimate substances. These properties are never possessed in their whole extent, and in all their purity, if that expression may be allowed. Their results are always influenced by the vital power, which constantly modifies the effects which seem to depend most immediately upon a physical, chemical, or mechanical cause, or upon any other agent whatsoever. Not so with the truly vital *extensibility*, which is so manifest in certain organs, as the penis and the clitoris. When excited, they become turgid and dilated by the afflux of humours, but that effect does not depend on a peculiar property, distinct from sensibility and contractility. These parts dilate, their tissue stretches under the action of these two properties, which would occasion the same phenomenon in all other parts, if their structure were similar.

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* The contraction of the membrane, formed by the expansion of the cremaster muscle, has doubtless assisted in rendering more distinct the appearance in question. This effect must be particularly distinct, at the moment of dividing the spermatic chord. The contractions of the same muscle corrugate the skin of the scrotum, when this part is exposed to cold, and draw up the testicles towards the inguinal rings. The contractility of the skin of the scrotum has but little influence in producing this effect.

The same applies to *caloricity*, or that power inherent in all living beings, of maintaining the same degree of heat, in varying temperatures. In consequence of which property, the human body preserves its temperature, of from thirty to forty degrees (of Reaumur's scale) under the frozen climate of the polar regions, as well as in the burning atmosphere of the torrid zone. It is by the exercise of sensibility and of contractility, that is, by the exercise of the functions over which these vital powers preside, that the body resists the equally destructive influence of excessive heat and cold.

If one were to admit *caloricity* as one of the vital properties, because, according to Professor Chaussier, that power of preserving a uniform warmth is a very remarkable phenomenon, one might be led to suppose, a distinct cause or a peculiar property to operate in producing other phenomena of no less importance.

Barthez and Professor Dumas have fallen into the same error, the former, in wishing to establish the existence of a power of permanent situation in the molecules of muscular fibres; the latter, in adding to sensibility and contractility a third property, which he terms the power of vital resistance. Living muscles are torn with much more difficulty than when dead, because the contractility which these organs possess in the highest degree, is incessantly tending to preserve the contact of the molecules, the series of which forms the muscular fibre, and even to draw them into closer connexion. This fact, which is brought forward as a proof of the existence of a peculiar power, is easily explained, on the principle of contractility.

Organized and living bodies resist putrefaction, from the very circumstance of their being endowed with life. The continual motion of the fluids, the re-action of the solids on the fluids, the successive and continual renovation of the latter, by the reception of new chyle, their constant purification by means of the secretions, through which the products animalized in excess are parted with, such are the causes which prevent the putrefactive action from taking place in bodies endowed with life, notwithstanding the multiplicity and the volatility of their elements. Their preservation is therefore a secondary effect, and depending on the exercise of the functions regulated by sensibility and contractility. Nature is distinguished for deriving a multitude of effects from a very small number of causes, it therefore shews a very imperfect acquaintance with her laws, to assign a separate cause to each fact.

The separation of the chyle, which takes place in the duodenum, from the admixture of the bile with the alimentary substance, the vivification of the blood by respiration, the secretion of the fluids in the conglobate glands, nutrition in the organs, are so many acts of the living economy, to which one might feel disposed to assign distinct causes; but these chemico-vital processes, are so subordinate to sensibility and contractility, that they are met with, only in organs endowed with these two properties, and they take place, in a degree more or less perfect, according to the condition of these properties in the organs in which they occur.

We have stated that there exist two great modifications of sensibility and contractility; that *sensibility* is divided into percipient *sensibility* and *latent sensibility*, that contractility is at times voluntary, at others *involuntary*, and that the latter may be *perceivable* or *insensible*.

SENSIBILITY.	*Perceiving.* (*cerebral, nervous, animal sensibility, perceptibility.*) With consciousness of impressions or *perceptibility;* it requires a peculiar apparatus.
	Latent. (*nutritive, organic sensibility.*) Without consciousness of impressions; or, general sensibility, common to every thing that has life; it has no peculiar organ, and is found universally diffused in living parts, animal or vegetable.

CONTRACTILITY.
- *Voluntary and sentient*, subordinate to perceptibility.
- *Involuntary and insensible*, corresponding to latent sensibility. Tonicity.
- *Involuntary and sentient.*

The cause of this last modification of contractility, appears to depend on the peculiar organization of the system of the great sympathetic nerves. From these nerves, the heart, the digestive canal, &c. seem to receive the power of exerting sensible contraction, an effect produced by the direct application of a stimulus, and over which volition has no controul, as will be stated in speaking of those nerves.

Sensibility and contractility offer a vast number of differences, the principal of which depend on the age, the sex, the regimen, the climate, the state of waking or of sleep, of health or of sickness, on the relative developement of the lymphatic, cellular or adipose systems, and on the proportions which exist between the nervous and muscular systems.

In the first place, the principle of sensibility and of contractility may, in its action, be likened to a fluid flowing from any source whatsoever, which is consumed, repaired, and drained by use, resupplied, or exhausted, equally distributed, or, occasionally concentrated on certain organs.

Secondly. Sensibility, like contractility, is very considerable at the instant of birth, and seems to diminish more or less rapidly till death.

Thirdly. The liveliness and frequency of impressions wear it out very early. It, in a manner, repairs itself, that is, recovers its original delicacy, when the sentient organs have been long at rest. Thus, an epicure whose taste has grown dull with high living, will recover all its accuracy, if during several months, instead of spiced ragouts and spirituous liquors, he lives on dry bread and plain water. In like manner, contractility becomes exhausted in the muscles which are too long employed, and it is recovered during the repose of sleep.

Fourthly. The following is an instance of the manner in which sensibility becomes concentrated on one organ, and appears to forsake the others: when the venereal excitement is in its highest degree, animals under its influence, receive blows and stings without pain.

Domestic animals in that condition, are often ill treated, without appearing to feel what is done to them. If the hind legs of the toad are cut off, at the time that he is holding the female firmly embraced, and is pouring his prolific seminal fluid on the ova which are issuing at her anus, he does not lose his hold, he seems insensible to every other sensation; as a man who is taken up with one thought, and absorbed in reflexion, is scarcely diverted from it by any means that can be employed. When during the influence of satyriasis, the vital power is carried to excess in the penis, patients have been known, (as we are told by Aetius) to cut off both their testicles, without suffering the pain usually attending so severe an operation. It is by this law of sensibility, that we are to explain the observation of Hippocrates, that two parts of the body cannot be in pain at the same time. If two pains come on at once, the more violent prevents the slighter from being felt; *Ambo partes non possunt dolere simul. Duobus doloribus, simul orientibus, vehementior obscurat alterum.* (Hipp.) In cases of scrophulous swellings, the parts are observed to inflame, to become painful, and suppuration occurs but rarely in every part at once, if the case is serious and attended with acute pain. The germ of a disease or of a slighter affection, may sometimes remain dormant under a greater pain. I was once overturned in a carriage, from the awkwardness of the coachman, the windows were broken and my wrists sprained. The right wrist which had suffered most, swelled first; I employed the proper treatment, and when at the end of a week, the swelling and pain had almost completely ceased, and the right hand was beginning to recover its suppleness and flexibility, the left wrist swelled and in its turn became pained; two complaints, if they may be called such, appeared in succession, and separately went through their regular course.*

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* John Hunter maintains from theory, the position that no two different fevers can take place at the same time in the constitution, but that if the two causes of disease exist together, the diseases themselves must be vicarious. And he verifies his reasonings from experience.

"On Thursday the sixteenth of may, 1775, I inoculated a gentleman's child, and it was observed that I made pretty large punctures. On the Sunday following, viz. the nineteenth, he appeared to have received the infection, a small inflammation or redness appearing round each puncture, and a small tumour. On

The perfection of one sense is never obtained, but at the expence of another; the blind who bestow more attention on the sensations communicated by the sense of touch and of hearing, often astonish us by the delicacy of these organs, so that, as has been observed, those who, to improve the human voice, have dared to mutilate their fellow creatures, by depriving them of the organs of generation, might have bethought themselves of putting out their eyes, to render them more sensible to the sweet impressions of harmony.

Fifthly. During sound sleep, the exercise of the percipient faculty, and that of voluntary contractility, are entirely suspended. During that state, it seems as if some covering were thrown over the sentient extremities. We know how hard the hearing becomes, how dull the senses of smell and of taste become, how dim the sight, a cloud spreading before the eyes, the moment we are falling asleep. *Vir quidam exquisitissima sensibilitate præditus, semi consopitus coïbat; huic, ut si velamento levi glans obductus fuisset, sensus voluptatis referebatur.*

Sixthly. Sensibility is more lively, and more easily excited, in the inhabitants of warm climates, than in those of northern regions. What a prodigious difference there is, in that respect, between the native of Germany and of the southern provinces of France. Travellers tell us, that there are in the neighbourhood of the poles, natives, so little endowed with sensibility, that they feel no pain from the deepest wounds. The inhabitants of the coast of North America, if we may believe the testimony of Dixon and Vancouver, thrust into the soles of their feet, sharp nails and

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the twentieth and the twenty-first, the child was feverish, but I declared that it was not the variolous fever, as the inflammation had not at all advanced since the nineteenth. On the twenty-second, a considerable eruption appeared, which was evidently the measles, and the sores on the arms appeared to go back, becoming less inflamed.

On the twenty-third he was very full of the measles; but the punctures on the arms were in the same state as on the preceding day.

On the twenty-fifth, the measles began to disappear, on the twenty-sixth and twenty-seventh, the punctures began again to look a little red. On the twenty-ninth, the inflammation increased, and there was a little matter formed. On the thirtieth, he was seized with fever. The small-pox appeared at the regular time, went through its usual course, and terminated favourably."

T. Hunter on Inflammation, page 5.

pieces of glass, without feeling the slightest uneasiness. On the contrary, the slightest prick from a thorn, for instance, in the foot, is in the strongest African, frequently followed by convulsions and locked jaw. The impression of the air, is alone sufficient to produce the same accident in the negro children in the colonies, the greater number of whom die of locked jaw, a few days after birth.

Montesquieu* very justly observed this difference which exists in the sensibility of the southern and northern nations, and he says of the latter, that "if you would tickle you must flay them."

Now, as the imagination is always proportioned to the sensibility, all the arts that are cultivated and brought to perfection, only by the exercise of that faculty, will flourish with difficulty near the icy polar regions, unless the powerful influence of climate be counteracted by well directed moral and physical causes.

Man is of all beings, the one that most powerfully resists the influence of external causes; and although the influence of climate is sufficient to modify his external appearance, so as to lead to a division of the species into several distinct varieties or kinds, this superficial impression is very different from the great alterations to which other beings are exposed, from the mere change of climate. Man is every where indigenous, and exists in all climates; while the plants and animals of the equator languish and die when conveyed to the polar regions. From the flexibility of his nature, man enjoys the power adapting himself to the most opposite situations, of establishing, between them and himself, relations compatible with the preservation of life. Nevertheless, it is not without difficulty that man undergoes these changes, and accustoms himself to new impressions. The periodical return of the seasons determines that of certain derangements, to which the animal œconomy is subject. The same diseases manifest themselves under the influence of the same temperature, and to use an ingenious comparison, resemble those birds of passage which visit us at stated seasons of the year. Thus, hemorrhages and eruptive affections come on with the return of the spring, summer comes attended by bilious fevers, autumn brings on a return of dysenteric affections, and winter abounds in inflammation of the lungs and other parts. The influence of climate, on the human body, does not shew itself merely in occasioning epidemic diseases, the consideration of which leads to the establishing what physicians call *medical constitutions.* This influence operates on man in health, as well as in sickness; and to say nothing of the alterations which our moral nature experiences from the tendency to love, rendered more impetuous with the return of spring, or of the melancholy to which nervous people are often subject towards the end of autumn, when the trees are shedding their leaves, the increase of growth is particularly remarkable at the time of the first growth of plants, as was observed again and again, by a friend of mine, physician to a large seminary.

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* This philosopher has borrowed from the father of physic, one of his most brilliant and paradoxical opinions. In his conception, warm climates are the seat of despotism, and the cold, the seat of liberty. This error is completely refuted in the profound and philosophical work of Volney on Egypt and Syria. He shews, that what Montesquieu has said of cold climates, applies to mountainous regions, while a champaign is more favourable to the establishment of tyranny. Hippocrates had said of the Asiatics, that their being less warlike than the Europeans, depended on the difference of climate, and likewise on the despotic form of their government. And he observes, that men who do not enjoy their natural rights, but whose affections are controuled by masters, cannot feel the bold passion of war.

See chap. XI. on the varieties of the human species.

Seventhly. Sensibility is greater in women and children; their nerves are likewise larger and softer, in proportion to the other parts of the body. In general, the principle of sensibility seems to decrease, in proportion as it has contributed to the developement of the acts of life; and the power of being impressed by external objects, diminishes gradually with age, so that there is a period of decrepid old age, at which death appears a necessary consequence of the complete exhaustion of that principle. In short, as I have said in describing the progress of death, at its approach, sensibility shews increase of activity and liveliness, as if its quantity required to be completely exhausted, before the termination of existence, or as if the organs made a last effort to cling to life.

The developement of the cellular and adipose substance, diminishes the energy of sensibility, the extremities of the nerves being more covered, and therefore not so immediately applied to the objects, the impressions which are felt, are more obscure. The fat operates on the nerves, as wool would do on vibrating chords, if wrapped round them, to fix them, to prevent their quiverings, and stop their vibrations.

Very nervous women are very thin; persons of much sensibility have seldom much *embonpoint.* Swine, in which the nerves are covered by a thick layer of fat, are the most insensible of all animals. The susceptibility of the nerves may be diminished, and their sensibility blunted by pressure. The application of a bandage firmly rolled round the body and limbs of an hysterical woman, will diminish the violence of her fits. In dressing wounds affected with what is called the hospital gangrene, I have often relieved the pain, by desiring an assistant to apply firm pressure above the sore.

Ninthly. There exists between the force of the muscles, and the sensibility of the nerves, between the sensible energy and the force of contraction, a constant opposition, so that the most vigorous athlets, whose muscles are capable of the most prodigious efforts, and of the most powerful contractions, are but slightly affected by impressions, and are with difficulty roused into action, as we have explained in giving a history of the nervous and muscular temperaments, which are characterized by this difference. Hence, man has more sensibility than the quadrupeds, although his nerves are smaller than theirs, which seem destined to set the muscles in action, and to serve as nerves of motion, rather than of sensation.

There is no muscular fibre, however minute, in which we are not obliged to admit the existence of a small nervous filament, to which it probably owes the power of contracting; contractility, at least voluntary contractility, does not appear to be inherent in the muscular fibre, nor independent of the nerves, through the medium of which, the will determines the action of the muscles; and if these last organs when insulated, contract on the direct application of a stimulus, is there not reason to suspect, that this stimulus acts on that portion of nerves which remains in the muscle, after it has been insulated, and which is intimately united to its fibres? The animals which have no distinct nervous system, possess at once in all their parts, sensibility and contractility; these two properties become blended in the organs, as well as in the phenomena of life, and can be perceived separate, only by a pure abstraction of the mind, which considers in succession the impression produced on these beings, and the motion of their substance, which is an immediate consequence of that impression.

We will not enter any farther into a consideration of the laws and phenomena of the vital properties, for fear of being led into useless repetitions, when we come to the history of the functions over which they preside. We will conclude what relates to them, by presenting the two most important features of their history, I mean, sympathy and habit.

§ VII. OF SYMPATHY.

There exist among all the parts of the living body, intimate relations; all correspond to each other, and carry on a reciprocal intercourse of sensations and affections. These links which unite together all the organs, by establishing a wonderful concurrence, and a perfect harmony among all the actions that take place in the animal economy, are known under the name of *sympathies.* The nature of this phenomenon is yet unknown; we know not why, when a part is irritated, another very distant part partakes in that irritation, or even contracts: we do not even understand what are the instruments of sympathy, that is, what are the organs which connect two parts, in such a manner, that when one feels or acts, the other is affected. But though beyond explanation, sympathy is not the less important in the economy of living beings; and these connexions between remote parts, constitute one of the most remarkable differences between those beings and inorganic bodies. Nothing similar is observable in dead or inanimate nature, in which all things are connected together, only by palpable and material links; here the chain is invisible, the connexion evident, the cause occult, and the effect apparent.

Whytt has clearly shewn, that the nerves cannot be considered as the exclusive instruments of sympathy, since several muscles of a limb which receive filaments from the same nerve, do not sympathize together, while there may be a close and manifest relation between two parts, of which the nerves have no immediate connexion, since each nervous filament having one of its extremities terminating in the brain, the other, in the part to which it is sent, remains distinct from those of the same trunk, and does not communicate with them.

Sympathies may be distinguished into different kinds. In the first place, two organs, which execute similar functions;—the kidnies may supply each other's office. When the uterus is in a state of pregnancy, the breasts participate in its condition, and there is determined into them a flow of humours necessary to the secretion which is to take place. Secondly. The continuity of membranes is a powerful source of sympathy. The presence of worms in the bowels, determines an uneasy pruritus around the nostrils. When there is a stone in the bladder, a certain degree of itching is felt at the extremity of the glans. The secretion of several fluids is determined in the same manner; thus, the presence of food in the mouth, brings at the extremity of the parotid duct, an irritation which extends to the parotid glands, calls them into action, and increases their secretion. Thirdly. If the pituitary membrane is irritated, the diaphragm with which it has no immediate organic connexion, nervous, vascular, or membranous, contracts, and occasions sneezing. Is not this sympathy one of those which Haller ascribed to a re-action of the *sensorium commune?* If the impression produced on the olfactory nerves by snuff, is too powerful, the uneasy sensation is transmitted to the brain, which determines towards the diaphragm, a quantity of the principle of motion sufficient to enable that muscle suddenly to contract the dimensions of the chest, so as to expel a column of air, that may detach from the pituitary membrane, the substances that are a cause of uneasiness to it. Fourthly. Does not the principle of life seem to controul at pleasure, the phenomena of sympathy? The rectum, when irritated by the presence of the excrements, contracts; what cause determines the accessory and simultaneous action of the diaphragm and abdominal muscles? Does this connexion depend on organic communications? Why, then, is not the sympathy reciprocal, and why does not the rectum contract, when the diaphragm is irritated? Fifthly. Can the repeated habit of the same motions explain the harmony which is observed in the symmetrical organs? Why, when our sight is directed to an object, placed laterally, does the rectus externus of the eye on that side, act at the same time as the rectus internus ofthe other eye? The indispensable utility of this phenomenon, in keeping a parallelism of the axis of vision is very obvious, but who can assign the cause? Why are rotatory motions, in different directions, performed with so much difficulty by the arm and leg of the same side of the body. Can it be called a just idea of the innumerable varieties of this phenomenon, and of its frequent anomalies, to say, with Rega, that there are sympathies of *action* or of *contractility (consensus actionum)* sympathies of *sensibility (consensus passionum.)*

All these difficulties render it pardonable in Whytt, to have considered the soul as the sole cause of sympathy; which was, in fact, a modest avowal of the difficulty of explaining the subject. We are not justified in considering sympathy as an anomalous action, as an aberration of the vital power. Can it be said, that the natural order of sensibility and irritability is inverted, in the sympathetic erection of the clitoris and of the nipple, or in the turgescence of the breasts, determined by the gravid state of the uterus?

It is by means of sympathy that all the organs concur in the same end, and yield each other mutual assistance. It affords us the means of explaining, how an affection at first local or limited in its extent, spreads, and extends to all the systems; it is thus that every morbid process is carried on. The diseases termed general, always originate, through the medium of association, in the insulated affection of an organ or a system of organs.

In fact, the affections which appear to us most complex, in the number, the variety and the dissimilarity of their symptoms, consist of only one, or of a small number of primitive or essential elements, all the rest are accessory, and depend on numerous sympathies of the affected organ, with the other organs of the animal economy. Thus, if the stomach is the seat of irritation, from foulness of its contents, pains of all kinds come on, but especially in the head and limbs, with a burning heat, nausea, loss of appetite, anxiety, and these symptoms constitute a disease which appears to affect the whole system.

To go on with the same illustration, the stomach, when oppressed by irritating substances, contracts spontaneously to get rid of them. The universal disturbance which their presence occasions, seems directed towards the same end, as if the suffering organ called upon all the others to assist in relieving it.

These *synergies*, or aggregate motions, tending to one end, and arising out of the laws of sympathy, constitute the diseases termed general, as well as the greater part of those which are called local. It is by means of them, and through these kinds of organic insurrections, if we may be permitted to use that expression, which perfectly expresses our meaning, that nature struggles with advantage, and rids herself of the morbific principle, or of the cause of the disease; and the art of exciting and directing these actions, furnishes the materials of the most important doctrines of the practice of medicine. I have used the terms excite and direct; for, it is necessary at times to increase, at others to diminish their intensity and force, and on some occasions to excite them, when nature, overwhelmed under disease, is almost incapable of re-action. This last circumstance belongs to the diseases of the most dangerous kind, if we include those in which the efforts of nature, though marked by a certain degree of energy, are without connexion, or consent, and frustrated by their want of coherence. The character of these affections was first well expressed by Selle, who substituted, for the term malignant, which used to be applied to them without any precise meaning, that of *ataxic*, which points out very correctly, the want of order, and the irregular succession of their symptoms.*

A knowledge of sympathies is of the highest importance in the practice of medicine.† When we wish to avert an irritation fixed in a diseased organ, experience and observation prove, that it is on the organ which bears to it the closest sympathetic connexions, that it is useful to apply medicines intended to excite counter irritation.

This might perhaps be the fittest place to inquire into the nature of those concealed relations which draw men together, and of those aversions which prevent their union; to discover the causes of those secret impulses which lead two beings towards each other, and force them to yield to an irresistible propensity. We might inquire into the reason of antipathy, and in a word, establish the complete theory of moral sentiments and affections. Such an undertaking is greatly above our strength, and besides, does not absolutely belong to our subject. It would require a considerable time, and who ever should undertake it, would be in considerable danger of losing his way at every step, in the extensive field of conjectures.

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* *Symptomata nervosa, nec inter se, neque causis manifestis respondentia.* Ordo tert. atactæ, C. G. Selle. Rudimenta pyretologiæ methodicæ.

† This information may be obtained, by consulting the works of the ancients, and especially of Hippocrates, who appears to have felt all the importance of this subject. Among the moderns, Vanhelmont, Baglivi, Rega, Whytt, Hunter, Barthez, and Bichat, have collected on this subject, a great number of facts obtained from experiments on animals, and especially from observations on diseases.

§ VII. OF HABIT.

It is easier to feel the meaning of this term than to define it. Habit, however, may be said to consist in the frequent repetition of certain acts, of certain motions, in which the whole body participates, or only some of its parts. The most remarkable effect of habit, is to weaken after a time the sensibility of organs. Thus, a catheter introduced along the urethra, and allowed to remain there, causes during the first day rather sharp pain, on the second day it feels less uneasy; on the third day, it is only troublesome, and on the fourth, the patient scarcely feels it. The use of snuff at first increases the secretion of mucus in the nose, but if continued a certain time, it ceases to affect the pituitary membrane, and the secretion would diminish considerably, but for the practice of increasing daily the quantity of that acrid powder; the presence of a canula in the nasal duct, after the operation for fistula lachrymalis, increases at first the mucous secretion of that canal; but in proportion as it becomes accustomed to the extraneous body, the secretion returns to its natural condition.

It is only by our sensations that we are aware of our existence. Life, to make use of the figurative language of system, of a modern writer, consists in the action of stimuli on the vital powers. (*Tota vita, quanta est, consistit in stimulo, et vi vitali.* Brown.) Sentient beings feel a continual necessity of renewed emotions; all their actions tend to the obtaining agreeable or disagreeable sensations; for, in the absence of other sensations, pain is sometimes attended with enjoyment. Those who have exhausted every kind of enjoyment, and who have had no pleasures ungratified, are led to suicide from a weariness of life; who can live, when all power of feeling is gone?

The following is the most extraordinary and remarkble instance known, of the manner in which habit and a frequent repetition of the same impressions, wear out by degrees the sensibility of organs. A shepherd, about the age of fifteen, became addicted to onanism, and to such a degree, as to practise it seven or eight times in a day. Emission became at last so difficult, that he would strive for an hour, and then discharge only a few drops of blood.

At the age of six and twenty, his hand became insufficient, all he could do, was to keep the penis in a continual state of priapism. He then bethought himself of tickling the internal part of his urethra, by means of a bit of wood six inches long, and he would spend in that occupation several hours, while tending his flock in the solitude of the mountains. By a continuance of this titillation for sixteen years, the canal of the urethra became hard, callous, and insensible. The piece of wood then became as ineffectual as his hand; at last, after much fruitless effort, G. one day in despair, drew from his pocket a blunt knife, and made an incision into his glans, along the course of the urethra; this operation, which would have been painful to any one else, was in him attended with a sensation of pleasure, followed by a copious emission. He had recourse to his new discovery, every time his desires returned. When after an incision into the cavernous bodies, the blood flowed profusely, he stopped the hemorrhage, by applying around the penis a pretty tight ligature. At last, after repeating the same process perhaps a thousand times, he ended in splitting his penis into two equal parts, from the meatus urinarius to the scrotum, very near to the symphysis pubis. When he had got so far, unable to carry his incision any farther, and again reduced to new privations, he had recourse to a piece of wood, shorter than the former: he introduced it into what remained of the urethra, and exciting at pleasure the extremities of the ejaculatory ducts, he provoked easily the discharge of semen. He continued this about ten years; after that long space of time, he one day introduced his bit of wood so carelessly, that it slipped from his fingers and dropped into the bladder. Excruciating pain and serious symptoms came on. The patient was conveyed to the Hospital at Narbonne. The Surgeon, surprized at the sight of two penes of ordinary size, both capable of erection, and in that state diverging on both sides, and seeing besides from the scars and from the callous edges of the division, that this conformation was not congenital, obliged the patient to give him an account of his life, which he did, with the details which have been related. This wretch was cut as for the stone, recovered of the operation, but died three months after, of an abscess in the right side of the chest, his phthisical state having been evidently brought on by the practice of onanism carried on nearly forty years.*

* Chopart, maladies des voies urinaires. Tome II.

The habit of suffering, renders us in the end insensible to pain; but every thing in this world is balanced, and if habit lightens our evils, by blunting sensibility, it on the other hand drains the source of our sweetest enjoyments. Pleasure and pain, these two extremes of sensation, in a manner, approximate to each other, and become indifferent to him who is accustomed to them. Hence arises inconstancy, or rather that insatiable desire of varying the objects of our inclinations, that imperious want of new emotions; hence we possess with indifference what we pursued with the utmost ardour and perseverance, and even cease to be impressed by those charms which once held us captivated.

A striking instance of the powerful influence of habit on the action of organs, is afforded by that criminal who, we are told by Sanctorius, was taken ill on being removed from a noisome dungeon, and did not recover till he was replaced in the impure air to which he had been long accustomed. Mithridates, that formidable rival of the Roman power, dreading to be taken alive by his enemies, tried in vain to put an end to his life, by taking large doses of the most subtle poisons, because he had long inured himself to their action.* It has, therefore, been justly said of habit, that it is a second nature, whose laws ought to be respected.

The organs of generation in women, in consequence of their lively sensibility, are in an especial manner submitted to the powerful influence of habit. The womb, after a miscarriage, has a tendency to a renewal of the same occurrence, when the same period of pregnancy recurs, so that the greatest precautions are necessary to prevent abortion in women, who are subject to it, when they have reached the month in which they before miscarried.

May not death be considered as a natural consequence of the laws of sensibility? Life, depending on the continual excitement of the living solids by the fluids which moisten them, ceases, because the parts endowed with sensibility and contractility, after long habitude of the impressions of those fluids, lose their capacity of feeling them. Their action gradually extinguished, would perhaps revive, if the energy of the stimulating power were increased.

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* In some very rare cases, habit produces a quite contrary effect. Cullen states, that he knew persons so accustomed to excite vomiting in themselves, that the twentieth part of a grain of tartar emetic was sufficient to excite a convulsive action of the stomach.

A knowledge of the power of habit, is a useful guide in the application of remedies, the greatest part of which operate in the cure of diseases, only by modifying sensibility. A wound in which lint has kept up the degree of inflammation necessary to cicatrization, becomes insensible to that application, the parts become spungy and soft, and the cure is protracted. The lint should then be covered with an irritating powder, and the pledgits soaked in an active fluid: one may safely increase the doses of a medicine which has been long employed. Thus, in the treatment of the venereal disease by mercurials, the dose is to be gradually increased; with the same view, Frederic Hoffman recommended in the treatment of chronic diseases, that the remedies should be suspended for a time and then resumed, lest the system should get accustomed to them and their influence be lost. The same motive should lead one to vary the treatment, and to employ, in succession, those medicines to which nearly the same qualities are assigned, for, each of them calls forth the sensibility in a peculiar manner. The nervous system may be compared to an earth abounding in various juices, and for a full display of whose fecundity, it is necessary that the husbandman commit to it the germs of various plants.

It is very remarkable that habit, or the frequent repetition of the same act, which uniformly, under all circumstances, and in all organs, blunts physical sensibility, should improve the intellect, and increase the facility, and activity of execution of all the operations of the understanding, or of the actions which depend on them. "*Habit impairs the sensitive power, and improves the judgment.* Bichat was therefore incorrect, when in his distinction of the organs which are subservient to the functions of assimilation, from those which serve to keep up our relation with the surrounding objects; he maintained, that the sensibility of the latter becomes more exquisite, while the sensibility of the former becomes impaired from habit.

But can a painter, because he judges more correctly than the ignorant, of the beauties of a picture, be said to see it better? Surely not, for, he may with a sight far less penetrating, and more infirm, form a more accurate analysis, from the habit which he has acquired, and judge with a great deal more promptitude and certainty, of the several parts and of the whole; just as the practised ear of the musician seizes, in a piece of music, and during the most rapid execution, the expression and the value of all the notes and tones. The error has arisen, from its being forgotten, that, correctly speaking, it is not the eyes that see, or the ears that hear; that the impressions produced by the sounds on these organs, are but the occasional cause of the sensation, or of the perception of which the brain is the exclusive seat. Which has the more delicate sense of hearing, the North American savage, who hears the noise of the step of his enemies, at distances that astonish us, or the artist who does not hear a person speaking at the distance of fifty paces from him, but who directs with judgment, all the operations of a great orchestra, and who distinguishes skilfully, the effect of each part?

Bring down to a frugal Pythagorean regimen, one of our modern epicures: his palate, exhausted of its sensibility by the most savoury dishes, by ardent liquors, and the most exquisite ragouts, will discover no taste in dry bread. Let him, however, live on bread, if he can, for some time, it will soon appear to him to have a grateful taste, as it does to those who make it their principal article of food, or who take it only with substances which have not a very distinct taste. Although with the sense of smell, that of taste furnishes us only with ideas the most directly connected with our preservation, those which most turn upon the wants of our animal nature: although we retain, with difficulty, the impressions of these senses, and that, to enable us to retain them, they must be often repeated; the epicure had so carefully analyzed them, that he had attained to the discernment of the faintest differences of taste, all those delicacies of sensation, which, as Montesquieu said, are lost to us vulgar eaters.

The motions, under the direction of the will, acquire by the precision of the determinations, the same aptness, facility, and readiness; and the dancer, who surprises us with his agility, has reflected, more than might be imagined, on the very complicated steps of which a ballet is composed.

Morbid sensibility, is equally under the influence of habit. I have always observed, that discharges from the urethra become less painful from their frequency. There is nothing down to disease itself, that is not made lighter by habit, as has been well observed by the old man of Cos.

It remains then demonstrated, even as a general thesis, that habit, or the frequent repetition of the same acts, whilst it regularly reduces physical sensibility, improves intelligence, and gives facility and promptness to all the motions that are under the direction of the will.

§ IX. OF THE VITAL PRINCIPLE.

The words *vital principle*, *vital force*, &c. do not express a being existing by itself, and independently of the actions by which it is manifested: it must be used only as an abridged formula, which serves to mark the total of the powers that animate living bodies, and distinguishes them from inert matter. So that, whenever, in the course of this section, I shall use these terms, or any equivalent, it is to be taken as if I had said, the aggregate of the properties and laws that regulate the animal economy. This explanation is become indispensable, now that several writers, realizing a mere abstraction, have spoken of the vital principle, as of something very distinct from the body, as of a being altogether separable, which they have invested with feeling, and thought, and even deliberate intentions.

From the furthest antiquity, the many and striking differences of living, and inorganic bodies, have led some philosophers to conceive in the former, a principle of particular actions, a force which maintains the harmony of their functions, and directs them all to a common end, the preservation of individuals and of the species. This simple and luminous doctrine has remained, even to our own days, only modified in its passage through many years: and, no one now disputes the existence of a principle of life, which subjects the beings that enjoy it, to a system of laws different from those which inanimate beings obey; a force, which might be characterized, as withdrawing the bodies it animates, from the absolute dominion of chemical affinities, which would else, from the multiplicity of their elements, act on them with great power; and, as maintaining them in a nearly equal temperature, whatever may be that of the atmosphere. Its essence is not in preserving the aggregation of constituent molecules, but in drawing to it other molecules, which by assimilation to the organs it prevades, replace those that are carried off in daily waste, and serve for their nourishment and growth.

All the phenomena that are to be observed in the living human body, might be brought as proofs of the principle which animates it. —The actions of the digestive organs on its food; the absorption, by the chylous vessels, of its nutritious parts; the circulation of these nutritious juices through the sanguineous system; the changes they undergo in their passage through the lungs, and the secretory glands; the impressibility by outward objects; the power of approaching or avoiding them; in a word, all the functions that are carried on throughout the animal economy, proclaim its existence. But it is customary to take a proof of it yet more direct, from the properties with which the organs of these functions are endowed. We have examined these properties, and we have seen that each of them presents us with, at least, two great modifications; that the last discovers three, which are, voluntary contractility, contractility involuntary and insensible, Stahl's tonic motion; and lastly, contractility involuntary and sensible, as that of the heart and the intestines.

If it is useful to analyse, in order to know, it is of equal importance not to multiply causes, from misconceiving the nature of effects. And if, on the one hand, the multitude of the phenomena of life, inclines us to the belief of many causes to produce them; the unfailing harmony that pervades all the actions, their mutual connexions, and reciprocal dependencies, point much more decisively to a sole agent, as causing, directing, and controuling these phenomena.

The hypothesis of the vital principle, is to the philosophy of living beings, what attraction is to astronomy. To calculate the revolutions of the planets, this science is compelled to recognize a force, which draws them constantly towards the sun, and constrains their tendency to fly from it, within the measured distance of those ellipses, which they describe around that common centre of light and heat, which dispenses to them, as they roll, the precious germs of life and of fertility. We are about to speak of this force, to which all the powers that animate each separate organ, join themselves, and in which all the vital powers are blended, but under the declaration, for the second time, of using the term only in a metaphorical sense. Without this precaution, I might lead you into all the false reasonings, which those have fallen into, who have assigned to it a real and separate existence.

The vital power is in perpetual strife with the powers that govern inanimate bodies. The laws of individual nature are, according to the saying of antiquity, for ever struggling against those of universal nature: and life, which is only this contest prolonged, in favour, altogether, of the vital powers, during health, but with uncertain issue in disease, is at an end, the moment in which the bodies endowed with it, fall again into the system of lifeless being. This constant opposition of vital to physical laws, both mechanical and chemical, does not withdraw, altogether, living bodies from the controul of these laws. There are effects always going on in the living being, chemical, physical, and mechanical: only these effects are constantly influenced, modified, and altered by the powers of life.

Why, when we stand up, are not all the humours carried down to the lower parts, by the force of gravitation? The vital power resists the completion of this hydrostatic phenomenon, and neutralizes this tendency of the fluids, the more succesfully as the the individual is more robust and vigorous. If it is one enfeebled by previous disease, the propensity will be but imperfectly repressed: the feet, after a certain time, swell: and this œdematous swelling can be ascribed only to the insufficient energy of the vital powers, which determine the distribution of the fluids, &c.

When a tumbler throws himself backwards, the blood does not flow altogether to his head, though this is become the lowest part; yet the natural tendency of fluids downwards is not altogether overcome; it is only diminished; for if he preserve long the same attitude, the struggle of the hydraulic and vital powers becomes unequal; the former prevail; they accumulate the blood upon the brain; and the man dies.

The following experiment proves incontestably, what has just been said of the power of resistance, which, in the human body, more or less, effectually counterbalances the force of physical laws. I applied bags filled with very hot sand, along the leg and foot of a man whose artery had been tied by two ligatures, in the hollow of the ham, for popliteal aneurism. Not only the limb was not chilled, which is what happens when the course of the blood is intercepted, but the extremity thus covered, acquired a heat much above the ordinary temperature of the body. The same apparatus applied to the sound leg, did not produce this excess of heat, certainly, because the fulness of life, in that limb, resisted the physical action.

The vital principle seems to act with the greater energy, as the sphere of its activity is narrowed; which has led Pliny to say, that it was chiefly in the smallest things that Nature has shown the fulness of her power.*

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* *Nusquam magis quàm in minimis est tota Natura.* Hist. Nat. lib. II. Cap. 2

The circulation is quicker, the pulse more frequent, the determinations more prompt, in men of short stature. Such was the great Alexander: never did man of colossal make, display great activity of imagination: none of them have glowed with the fire of genius. Slow in their actions, moderate in their desires, they obey, without murmuring, the will that governs them, and seem made for slavery. Agrippa (says Omilius Probus, in his History of Augustus) advised that they should disband the Spanish guard, and that in its room, Cæsar should choose one of German, "wotting "well, that in these large bodies, there was little of coverte malice, "and yet lesse of subtiltie, and that it was a people more minded "to be ruled than to rule."

To judge soundly of the remarkable difference which inequality of stature brings into the character, compare extremes; set against a Colossus, a little man of diminutive stature; granting, nevertheless, to this last, full and vigorous health. You may guess that he is talkative, stirring, always in action, always changing his place: one would say that he is labouring to recover in time, what he has lost in space. The probable reason of this difference in the vital activity, following the difference of stature, arises from the relative bulk of the primary organs of life. The heart, the viscera of digestion, &c. are of nearly the same bulk in all men: in all, the great cavities are nearly of the same extent, and it is principally in the length of the lower limbs, that the difference of stature will be found to lie. It is easily conceivable, that the viscera supplying the same quantity of nutritious juices to a smaller bulk, that the heart giving the same impulse to blood which is to traverse a shorter course, all the functions will be executed with greater rapidity and energy.

By an obvious consequence, the diseases of little men, have a more acute character; they are more vehement, and tend more rapidly to their crisis. They have in them something of the velocity, I would even say the instability of morbid re-action during infancy. There is nothing even to the duration of life, on which the differences of stature have not some influence. With this suspicion, and some curiosity to ascertain its justness, I have made enquiries in the hospitals, where people in advanced life are taken in, and I found them, for the most part, occupied by old men above the middle size; so that reasoning and observation concur in showing that, all things else being equal, those of superior stature, have a grounded hope of prolonging their life beyond the ordinary term.

I have observed, with many others, that the whole body unfailingly receives an increase of vigour, from the amputation of a limb. Frequently, after the loss of a part of the body, you will see a manifest change take place in the temperament; those that were weak, even before the disease which brings on the necessity of the operation, becoming robust; affections, chronic from debility, such as scrophula, tabes mesenterica, dissipated; glandular swellings resolved; which indicates a very remarkable increase in the actions of all the organs.*

The parts most remote from the centre of circulation are, in general, less alive than those which are nearer. Wounds of the legs and feet, are more liable to ulcerate, because, besides the circulation of the fluids, which the slightest weakness greatly retards in them, their life is too feeble for their wounds to go quickly through their periods, and readily cicatrize. The toes freeze first, when we remain too long exposed to severe cold: it is in them too that the mortification begins, which sometimes attacks a limb after the ligature of its vessels.

Thus, although we may say, that the principle of life is not seated in any part of our being, that it animates every system of organs, every separate organ, every living molecule, that it endows them with different properties, and assigns to them, in some sort, specific characters, it must be confessed, that there are in the living body some parts more alive, from which all the others seem to derive motion and life. We have already seen, that these central organs, these foci of vitality, in whose life that of the whole body is involved, diminish gradually in number in the animal kinds, as they are more removed from man, whilst the fewer they are, the more they are spread out over the body; so that life is more generally diffused, and its phenomena less rigorously and strictly connected, as we descend in the scale of being, from the red- and warm-blooded, to the red- and cold-blooded animals, from these to the mollusca, the crustacea, worms and insects, to the polypus, who forms the extreme link of the animal chain, and lastly, to plants, of which not a few, like the zoophytes, so similar to them in many respects, are endowed with the remarkable property of reproduction by slips; which implies, that each part contains the aggregate of organs necessary to life, and can exist alone.

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* The extraordinary developement of an organ, never takes place but at the expence of those about it, of which it draws off the juices. Aristotle observes, that the lower extremities are almost always dry, and wasted in those who are of ardent temperament, or in habits of frequent venery. Hippocrates relates in his work (*De aere, locis, et aquis*, Foës: fol. 293.) that the Scythian women seared their right breast, that the arm on that side might grow in size and strength. Galen speaks of Athletes, who, in his time, kept the sexual organs in the most entire inaction, that withered, shrunk, and perished, in some sort, by this absolute repose, they might not draw off the nutritious juices from the sole nourishment of the muscular organs. A young man, who has several times carried off the prize by running at the public fêtes, abstains from venery for some months, before entering the lists, in perfect certainty of victory, after this privation.

The vital principle has by some been confounded with the rational soul; but others have distinguished it from that emanation of divinity, to which as much as to the perfection of his organization, man owes his superiority to all the animal kinds. What bond unites the material principle, which receives impressions and transmits them, to the intelligence which feels, perceives, examines, compares, judges, and reasons on them? Were man one, says Hippocrates, did his material principle make up his whole nature, pleasure and pain would be as nothing to him; he would be without sensation: for, how could he account to himself for impressions? *Si unus esset homo, non doleret, quia non sciret unde doleret.* Here we stand on the confines of physiology and metaphysics: let us beware of setting foot in the dim paths that are before us: the torch of observation would yield but ineffectual light, too faint to dispel the thick darkness that lies over them.

The vital power is merely the *vis medicatrix naturæ*, more powerful than the physician, in the cure of many diseases; the art of the physician consisting, in most cases, in awakening or directing the action of that power. When a thorn is thrust into a part endowed with sensibility, a sharp pain is felt, the fluids rush in abundance to the part, it becomes red and swollen; all the vital powers are excited, the sensibility becomes more acute, the contractility greater, and the temperature rises. Does not this increase of vital energy in the injured part, this process which takes place, around the substance that is the cause of the disorder; those means which are provided to expel it, indicate the existence of a preserving principle, incessantly watching over the harmony of the functions, and struggling against all the powers that may tend to interrupt its exercise, or to annihilate the vital motion?

Theory of inflammation. Inflammation may, I believe, be defined; *the increase of vital properties in the part which it affects.*

Sensibility becomes more acute in the part so affected, its contractility greater; and from that increase of sensibility, and action, arise all the symptoms characteristic of inflammation. Thus the pain, the swelling, the redness, the heat, and the difference in the state of the secretions, denote in the part, a more energetic and active vitality.

Those who have objected to the definition which I have given of inflammation, have evidently mistaken the functions of the organs for their properties. It is very true, that inflammation of the eye is attended with loss of sight, but that circumstance depends on the opacity of the transparent parts which should transmit the luminous rays to the retina. The sight is prevented by a mechanical obstacle, but the sensibility of the organ is augmented, to such a degree, that the faintest light reaching the bottom of the eye, through the transparent cornea dimmed by the congestion of the vessels, causes in it intolerable pain. On this principle, darkness is universally recommended to patients affected with ophthalmia. In like manner, when a muscle is inflamed, the action of the fibre, its decurtation, is prevented by the congestion in the cellular membrane, which covers it, and fills its interstices. The cause preventing contraction, or the exercise of contractility, is mechanical, and may be compared to that, which, in an inflamed lung, opposes the admission of air, and the passage of the blood, from the right to the left side of the heart. Can any one call in question, the increase of vital action in peripneumony? I am therefore of opinion, that the above definition is better than that proposed by Bichat, in his "Anatomie generale," a work of later date than the first edition of these elements of physiology, and in which he makes inflammation to consist in the increas of those vital properties, which he terms insensible.

All the parts of the human body, with the exception of the epidermis and its different productions, as the nails and the hair, appear capable of inflammation. One might include among these "epidermoid" parts, certain dry and slender tendons, as those of the flexors of the fingers, which when pricked, lacerated and irritated in a thousand ways, are insensible to pain, and remain uninjured in the midst of a whitlow, though attended with suppuration of all the neighbouring soft parts; and when exposed to the air, they exfoliate instead of granulating. Organization is so indistinct in all these parts, life so feeble and languid, that they remain insensible to the impression of all those causes which might tend to increase its activity.

The degree of sensibility in a part, the number and size of the nerves and vessels which are sent into it, determine the degree of its aptitude to inflammation; thus the bones and cartilages inflame with considerable difficulty. When one of these parts is laid bare, the first effect of the irritation to which it is exposed, is a softening of its substance. When a bone is laid bare, it becomes cartilaginous and softens, in consequence of the absorption of the phosphate of lime which fills up the interstices of its tissue; and it is only after this kind of incarnation, that fleshy granulations begin to sprout, as may be observed on the extremities of bones after amputation. The difficulty with which inflammation is set up in the harder parts of the body, explains why, before the twelfth or fifteenth day after a fracture, it is of little consequence towards union of the bone, that the fractured ends should be placed in apposition; not-that is it right to wait so long, before applying the proper bandages, which are indispensable from the first, to prevent the pain and laceration occasioned by the displaced bones. The blood is determined, from all quarters, towards the irritated and painful part, which swells and assumes a red colour, from the presence of that fluid. The swelling would be unlimited, if, at the same time that the arteries increase in power and caliber, to occasion that determination, the veins and lymphatics did not acquire a corresponding energy, to enable them to relieve the part, of the fluids which have accumulated in it, and which irritation is constantly determining to it. The power of irritability and contractility increases with sensibility; the circulation is more rapid, in the inflamed part; the pulsations of the capillary vessels are manifest. The part is likewise hotter, because, in a given time, there passes through its tissue more arterial blood, from which a larger quantity of caloric is disengaged, and the continued effects of the pulmonary respiration are better marked in it than in any other organ.

It forms no part of our intention to treat of the varieties of inflammation: they depend principally on the structure of the organ which is affected, on the violence and rapidity of the symptoms, and on its effects.

Is not the turgescence of an inflamed part, occasioned in the same manner, as in parts subject to erection, as the corpora cavernosa of the penis and of the clitoris, the nipples, the iris, &c.? In erection of the penis, as in inflammation, there is an irritation, a determination of fluids to the part, an increase of sensibility and contractility; yet its condition is not that of inflammation. Nature has so disposed the organization of these parts, that they can sustain, without injury, those instantaneous augmentations of vital energy, necessary to the exercise of the functions performed by the organs to which they belong. As in inflammation, these congestions disappear, when the cause of irritation has ceased to act; thus, the pupil dilates, because the iris recedes, when the eye is no longer exposed to the rays of a vivid light. The penis returns to its naturally flaccid and soft state, when no irritation operates to determine to it the fluids whose presence, as long as the erection lasts, is easily explained by the continuance of the irritation, without its being necessary to have recourse to mechanical explanations, to account for that phenomenon. When the irritation, which produces the vital turgescence of the penis or iris, is carried too far, or continues too long, the natural congestion becomes morbid. It is well known, that priapism is frequently attended with mortification of the penis, and that the too long continued action of light on the eye, brings on inflammation of that organ.

The preceding observations on inflammation, shew, that an acquaintance with its phenomena is useful, even in a physiological point of view. The vital processes, which in some organs take place in so obscure a manner, that they are imperceptible, acquire in inflammation a character of rapidity and intensity, which renders it much easier to observe and recognize them. Considered in a general and abstract point of view, and merely with a reference to its object, inflammation may be considered as a means employed by nature, to repel the influence of noxious agents, which, when introduced within the body, or on its surface, she has no power of resisting, but by a more active developement of the powers which animate it.

During the severe winter of 1793, the chemist Pelletier repeated the celebrated experiment of freezing mercury, and obtained a solid ball in the bulb of a barometer, which he had for a long while kept immersed in the midst of a quantity of ice, continually moistened with nitric acid. When the metal had attained a completely solid state, he drew the ball from the bulb, and placed it on his hand. The heat of the part, joined to that of the atmosphere, soon restored the quicksilver to its fluid state: at the same instant he experienced in his hand so intolerable a degree of cold, that he was obliged to drop the quicksilver instantly. There soon came on, in the painful and chilled part, a phlegmonous inflammation, which was cured by resolution. Quicksilver, in a solid state, is one of the coldest bodies in nature: how very rapidly the caloric must have been carried off in this case, and how deep the impression must have been in the palm of the hand, doubly affected by the cold, and by the vital re-action, which terminated in inflammation! I have produced a similar effect, by endeavouring to melt a piece of ice in my hand, during the heat of summer. In this experiment, the impression of cold is soon succeeded by a sensation of acute pain and extraordinary throbbings, in the hand and fore arm. When the two hands are afterwards compared, that which held the piece of ice is extremely red, from the congestion of blood in the cutaneous capillary tissue, and is very different in its appearance, from that which was not the subject of experiment.

Analogous facts, if seriously considered, should induce the followers of Brown to apply to the effects of cold, the distinctiction which he applied to debility, of direct and indirect. They would have no difficulty in ascertaining, that in its medical application, that negative state of caloric, which is directly debilitating, may, nevertheless, by the re-action which it excites, be considered as an indirect tonic.

§ X. OF THE SYSTEM OF THE GREAT SYMPATHETIC NERVES.

The great sympathetic nerves are to be considered as the bond destined to unite the organs of the nutritive functions, by whose action man grows, is evolved, and incessantly repairs the continual waste attending the vital motions. They form a nervous system, very distinct from the system of the cerebral nerves; and, as the latter are the instruments of the functions by which we hold intercourse with external objects, the great sympathetic nerves supply motion and life to the organs of the inward, assimilating, or nutritive functions.

In animals, without vertebræ, may not the nervous system, which floats in the great cavities with the viscera which they contain, be considered as consisting entirely of the great sympathetics?

These nerves are principally distributed to the organs of inward life, whose activity, in those animals, seems to grow, in proportion as their external senses, and their faculty of locomotion, are imperfect. If the great sympathetics exist in all the animals which have a distinct nervous system, do they not, in an especial manner, contain the principle of vegetable life, essential to the existence of every organized body possessing the power of digestion, absorption, circulation, secretion and nutrition? Finally, is it not probable, that in man the system of the great sympathetic nerves, has a very great share in occasioning a number of diseases, and that the impressions with which patients are affected, are referred to their numerous ganglions, while the brain is exclusively the seat of intellect and thought?*

These suggestions will, doubtless, be answered in the affirmative, if one consider the origin, the distribution and the peculiar structure of these nerves, the acute sensibility of their branches, as well as the disorders attending their injury.

Extended along the vertebral column, from the base of the skull to the lower part of the sacrum, these great nerves, in some measure parasitic, do not arise from the branches supplied them by the fifth and sixth pairs arising from each side of the brain: they live and are nourished, as it were, at the expence of all the nerves of the spinal marrow, from which they receive branches, so that there is not one of them, from which one can say, that the great sympathetics arise exclusively. The numerous ganglions which are distributed along their course, divide them into so many small systems, from which arise the nerves of the organs nearest to them. Amid these bulgings, considered by several physiologists, as so many little brains, in which is performed the elaboration of the fluid which they transmit to the nerves, no one is of more importance than the semi lunar ganglion, situated behind the organs which occupy the epigastric region, and from which those nerves originate, which are distributed to the greater part of the viscera of the abdomen. It is to the region occupied by that ganglion, in which the great sympathetic nerves unite, and which may be considered as the centre of the system formed by their union, that we refer all our agreeable sensations; there it is that we feel in sadness, a constriction which is commonly referred to the heart. Thence, in the sad emotions of the soul, seem to originate those painful irradiations which trouble and disorder the exercise of all the functions.*

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* These opinions on the uses of the great sympathetic nerves, are explained in my Essay on the connexion of Life with the circulation. This Essay was published before any thing that has appeared on the same subject.—Consult the "Memoires de la Société Médicale pour l'an VII."

The numerous filaments of the great sympathetic nerves are finer, they are not of the same whitish colour, nor of the same consistence as the filaments of the cerebral nerves. On that account, they are less easily dissected, the nervous fibrillæ are less distinct, their reddish chords are moister, and they appear formed of a more homogeneous substance: their membranous coverings are less considerable. They are likewise endowed with a more acute and more delicate sensibility. Every one knows the danger attending wounds of the mesentery, a membranous duplicature, in itself insensible, but containing such numerous nerves destined to the intestinal tube, that the most pointed instrument can scarcely wound the mesentery, without injuring some of their branches. The pain attending affections of the great sympathetic nerves, is of a very peculiar kind; it leads directly to the extinction of the vital power. It is a well-known fact, that a bruise of the testicles overpowers, in a moment, the strongest man. Every one knows, that patients who die of strangulated hernia, of volvulus, or of every other affection of the same kind, die in the most distressing anguish, their heart feels oppressed, and they are tormented with constant vomiting. Intestinal and nephritic colics are attended with the same sort of pain; that attending injection of the tunica vaginalis in hydrocele, is of the same kind. And one expects a favourable event of the operation, only in those cases in which the patient has felt pain along the spermatic chord, in the course of the spermatic nerves, which arise, as it is well-known, from the renal plexus. In three cases of wounds of the abdomen. I was led by the nature of the pain which the patients suffered, to prognosticate that the wounds had penetrated; the event justified my prognostic. In all these affections of the great sympathetic nerves, the pulse is frequent and hard, the face is covered with a cold sweat, the features are sunk; all the symptoms are alarming and soon terminate fatally.

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* Consult on the subject of the epigastric centre, Van Helmont, who calls it the *archeus;* Buffon, Bordeu, Barthez and Lacaze, who give it the name of the *phrenic centre*, because they ascribe to the diaphragm, what belongs to the nervous ganglions placed in front of its crura.

The use of the system of the great sympathetic nerves is, not merely to establish a closer connexion and a greater union between all the organs which perform the functions of assimilation, but likewise to free those parts from the influence of the will. A power of the mind so fickle and so varying, that life would be in constant danger, if we had it in our power to stop or suspend the exercise of functions with which life is essentially connected.

If we consider what are the organs to which the functions of assimilation are intrusted, and which receive their nervous influence from the great sympathetic nerves, we shall find, that the action of the greater number, is wholly independent of the controul of the will.* The heart, the stomach, the intestinal canal, &c. do not obey the will, and seem to possess a more insulated and more independent existence, and to act and rest, without any influence on our part. Some of these organs, as the bladder, the rectum, and the muscles of respiration, which do not receive their nerves exclusively from the great sympathetics, are obedient to the will, and receive from the brain the principle of motion, the former, from the branches which the sacral nerves send to the hypogastric plexuses: the diaphragm, from the nerves which it receives from the fifth and sixth cervical pairs.

The great sympathetic nerves supply the diaphragm, the rectum, and bladder, only with nerves of sensation. This provision was a very necessary one, for, if, as is the case with the heart, and the intestines, these parts had received their nerves of motion from the great sympathetics, their action would have been independent of the will, as is the case with all the parts which these nerves supply with motion. The bladder and rectum, placed at the extremities of the digestive apparatus, and destined to serve as reservoirs to the excrementitious residue of our solid and liquid aliments, would have been constantly evacuating their contents, as fast as the substances which are destined to be retained within them for some time, reached their cavity.

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* All those parts which receive their nerves from ganglions, are equally independent. Professor Chaussier thinks, that the upper filaments of the great sympathetic nerves, ascend along the internal carotid, and join the spheno-palatine and lenticular ganglions.—M. Ribes thinks he has ascertained by dissection, that several very long and slender filaments follow the course of the branches of the internal carotid, and like them are sent to the base of the brain, beyond which they cannot be traced. I have myself observed, in dissection, these filaments around the branches of the internal carotid artery, but I had always considered them to be formed of cellular substance.

On the other hand, if the diaphragm had received its nerves of motion from the great sympathetics, respiration would have ceased to be a voluntary function, of which we might at pleasure accelerate, slacken, or even completely suspend the action. To prove that the act of respiration is under the controul of the will, we may have recourse to analogy, and adduce the instance of reptiles, as lizards, frogs, serpents, salamanders, and toads, which are cold-blooded animals, and in which this function is manifestly voluntary. We may further mention those slaves, who, we are told by Galen, put themselves to death, when summoned before their executioners or judges. According to that physiologist, and others, they choked themselves, by swallowing their tongue. But it is sufficient to know how the muscles that bind down the tongue are situated, and the degree of motion which they allow, to see how little ground there is for that opinion. The action of the brain would, in that case, have been no longer necessary to the maintenance of life; in an animal without a brain, respiration would have continued, and the circulation would not have been interrupted. The death of that viscus would not have been attended with the sudden death of all the rest.

The nerves which arise from the spinal marrow, and which give to the diaphragm the power of contraction, a power which that muscle loses suddenly, if these nerves be tied, appear to me the chief links which unite the internal assimilating or nutritive functions, to those which keep up the relation of the animal with external objects. Without this bond of union, the series of vital phenomena would have been less close, and their dependence less necessary. Had it not been for the necessity that the diaphragm should receive from the brain, by means of the phrenic nerves, the principle which determines its contractions, acephalous animals, which are born without that organ, might continue to live as they did before birth, when the organs of nutritive life received blood, which had undergone, in the lungs of the mother, the changes necessary to life. But where the bond which united them to the mother is destroyed, obliged themselves to produce in their fluids, the necessary changes, by the inhalation of the vivifying principle contained in the atmosphere, they no longer can obey that necessity; the organs of respiration are deficient in the principle which should excite them.

When an internal inflammation is of small extent,* and is seated in a part in which there are not many nerves, and whose tissue yields easily to the humours which irritation determines into it, the whole morbid action takes place in the affected part, and the general order of the functions is not sensibly deranged. But when inflammation takes place in a part endowed with much sensibility, or of a close texture, as the fingers and toes, then fever comes on, because a sympathy in the morbid action takes place, between the diseased part and the rest of the system. This diffusion of the local action almost infallibly takes place, when inflammation occurs in one of the organs of the assimilating functions. This effect may be considered as uniform, though Morgagni mentions several instances of inflammation of the liver, marked by no peculiar symptoms.

A knowledge of the great sympathetic nerves accounts for this difference. When an external part is affected with inflammation, the irritation which it suffers, is by means of its nerves propagated to the brain, which by a re-action, called by Vicq-d' Azyr (who on this subject has only developed the opinions of Vanhelmont) internal nervous action, transmits that irritation to the heart, to the organs of respiration, of digestion and of secretion, in which the phenomena, denoting a febrile state, are principally evolved. When, on the contrary, the heart, the lungs, or any other internal organ is affected with acute inflammation, all the viscera partake in the derangement with which any one of them is affected, and without the intervention of the brain. They are all intimately connected by the filaments which they receive from the great sympathetic nerves; and, by means of that nervous system, which is in especial manner appropriated to them, they carry on a more intimate intercourse of sensations and affections. Besides, the derangement of the important functions entrusted to the diseased organs, is necessarily attended with proportionate changes in all the acts of the animal economy, in the same manner, no doubt, as the defect of one wheel interrupts or disturbs the mechanism of the whole machine.

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* A thousand pustules in the small pox occasion only a moderate degree of fever, if they are at a distance from each other; but if the disease is confluent, that is, if the pustules are close together and run into each other, the fever becomes considerable and the patient's life is endangered. The fleshy granulations which sprout in abundance from an ulcerated surface, are so many small phlegmons unaccompanied by a febrile state, but if brought close to each other by irritation, that condition will not fail to ensue. Vaccination is not, in the greater number of cases, attended by the slightest febri leaction, if, as I always have done, the punctures are made at a certain distance from each other, so that the inflammatory areolæ may not run into each other [illegible]

There exists in the stomach an union of the cerebral and sympathetic nerves, which explains the manifest dependency, in which that one of the three supports of life is found with the brain; a dependency so marked, that every strong affection of the soul, every violent agitation of the mind, weakens or even totally suspends the action of digestion in the stomach.—This combination of cerebral and sympathetic nerves likewise accounts for a phenomenon, which was mentioned in speaking of the influence of habit on the action of the organs. The stomach differs essentially from the intestinal canal; for, far from getting accustomed to the impression of emetics, so as to become by degrees less sensible to their action, as the intestines to the action of purgatives, though three grains of tartar emetic could, at first, scarcely excite it, half a grain only of that salt is able to bring on vomiting, when by frequent use, it has acquired the habit of the motions excited by its action. Is it not in that case with the stomach, as with a limb, whose muscles perform motions with the greater ease and facility, when they have been often practised.

§ XI. OF THE RELATIONS OF PHYSIOLOGY TO SEVERAL OTHER SCIENCES.

It would be entertaining a very incorrect notion of the science of living man, to imagine with some authors, that it solely consists in the application of the laws of Natural Philosophy, to the explanation of the phenomena of the animal economy. Physiology is an independent science; resting upon truths of its own, which it draws from the observation of those actions, which, in their aggregate succession and connexion, constitute life. It is enriched, it is true, with facts furnished to it by Natural Philosophy, Chemistry, and Mathematics; but what it has borrowed from these, is accessory merely, and does not form an essential part of the edifice of the science. Thus, the better to understand the mechanism of hearing and vision, physiology borrows from acoustics and optics, elementary notions on sound and light; and, in order to obtain a more correct knowledge of the nature of our solids and fluids, and of the manner in which animal substances are constantly passing from the one to the other of these two conditions, physiology calls in the aid of chemistry. Thus, geometry and mechanism furnish it with the means of better understanding the advantageous form of the organs, and the perfection of their structure.

No study carries along with it a more lively interest, than that of the admirable relations existing between the conformation of our parts and the external objects, to which they are applied. These relations are calculated with such precision, and laid down with such accuracy, that the organs of sense and of motion, considered in this point of view, may be regarded as the model of the most ingenious productions of art. So true it is, in the words of the great physician of Pergamus, that nature did every thing before art, and better.*

At the beginning of the last century, geometrical physicians, deceived by an appearance of rigid precision, attempted to explain every thing by the calibre of vessels, their length, their curvatures, the compound ratio of the action of solids and the impulse of fluids. Hence were formed theories so very imperfect, that, as we shall see, in treating of several points of physiology, and especially of the force with which the heart acts, not one of those who proposed them, coincides with those who have since followed their track. However, it does not admit of a doubt, that there occur in the animal machine, effects which are referable to the laws of hydraulics. The brain, for example, required a large and constant supply of arterial blood, vivified by recent circulation through the lungs; but the too rapid and abrupt access of that fluid in the brain, might have disordered its stucture. Nature, therefore, has, as we shall mention in the article of the cerebral circulation, employed all the hydraulic resources in her power, to break the force with which the blood enters the brain, and to slacken its course.

Has man ever applied the laws of hydraulics in a more felicitous manner than nature, in the rete mirabile formed at the base of the brain by the carotids of quadrupeds? An arrangement truly remarkable, without which, the blood conveyed to the brain by those arteries, impelled by a force superior to that of the human heart, and not having to overcome the resistance of its own gravity, would infallibly have occasioned a disorganization of that organ, whose consistence is so soft.

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* *Quandoquidem natura, ut arbitror, et prior tempore sit, et in operibus magis sapiens quàm ars.*

GALENUS, *de usu partium*, lib. VII, cap. 13.

It was from observing the manner in which nature prevents the diffusion of light in the globe of the eye, that Euler was led to the improvement of his astronomical telesopes.

As to the application which is allowable of mathematical sciences, it may be said, that, as in physiology, but little is absolutely certain*, and much merely probable, we can reckon only on probabilities, and seek our elements in facts deduced from observation or experience: facts, which when collected and multiplied to a certain degree, lead to results of equal value with truths absolutely demonstrated.

The phenomena presented by living bodies vary incessantly, in their activity, their intensity, and their velocity. How can mathematical formulæ apply to such variable elements? As well might you inclose in a frail vessel, hermetically sealed, a fluid subject to expansion, and of variable bulk. The motions of progression in man and in the animals, afford, nevertheless, sufficiently correct applications of calculation. Calculation may likewise be applied with advantage, to the measurement of the results of our different secretions, to ascertain the quantity of air, or of aliment, introduced into our organs, &c.

Among the principal causes which have retarded, in a considerable degree, the progress of physiology, may be enumerated the mistake of those who have endeavoured to explain all the phenomena of living bodies, by a single science, as chemistry, hydraulics, &c., while the union of all these sciences will not account for the sum of these phenomena. The abuse, however, of these sciences, should not be a reason for setting them aside altogether. The facts obtained from natural philosophy, chemistry, mechanics, and geometry, are so many means applicable to the solution of the great problem of the vital economy; a solution which, though as yet undiscovered, should not be considered as unattainable, and to which we shall approach the nearer, as we attempt it with a greater number of data. But it cannot be too often repeated, that he alone can hope for that honour, who, in the application of the laws of natural philosophy to living bodies, will take into account the powers inherent in organized nature, which controul, with supreme influence, all the acts of life, and modify the results that appear most to depend on the laws by which inorganic bodies are governed.

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* This is to be understood, as applying only to the causes of the phenomena, and not to the phenomena themselves; for physiology is perhaps richer than any other science, in facts unquestionable, and easily ascertained by observation.

Anatomy and physiology are united by such close relations, that it has been an opinion with some, that they are absolutely inseparable. If physiology, say they, has for its object, a knowledge of the functions carried on by our organs, how is one to understand their mechanism, without knowing the instruments by which they are performed? One might as well attempt to explain the manner in which the hand of a watch performs the circle of its diurnal revolution, without understanding the springs and numerous wheels which set it in motion. Haller is the first who established the connexion between anatomy and physiology, and who illustrated it in his great work. Since Haller, a great number of anatomists, and among them Sœmmering,* in a work recently published, have combined, as much as possible, these two sciences; the latter, in treating separately of each system of organs, explains what is best known of their uses and properties.

However close the connexion between anatomy and physiology, they have, nevertheless, appeared perfectly distinct to the greater number of authors, and we have several valuable works on anatomy, of which physiology occupies but a small part.—This manner of embracing the two sciences appears to me attended with the greatest advantage; in fact, if the insulated description of organs suffices to the physiologist who wishes to study their functions, that method is attended with the disadvantage of furnishing few truly useful views, in the practice of operative surgery. To render the knowledge of the human body more especially applicable to the practice of surgery, it is necessary, not only to consider separately the different parts, but likewise to view them in their connexion, and to determine precisely their relations. The anatomist, who knows that the principal artery of the thigh is the crural,—that, continued under the name of popliteal, it passes behind the knee in its way to the leg,—that, in its course, it supplies with branches different parts of the limb,—even though he knew perfectly the name, the number of these branches, the varieties to which they are subject, the parts to which they are distributed, would nevertheless possess a knowledge

* J. Ch. Sœmmering, *de corporis humani fabricâ.* 6 vols. 8vo. 1804.

of that branch of the system, almost useless in the treatment of the diseases with which it may be affected. The situation of the artery, its direction, the parts which surround it, its precise relations to each of them, its superficial or deep seated course, &c. are the only circumstances from which he can derive any advantage.

He who, in this point of view, cultivates anatomy, may be compared to the chemist; in the same manner as the latter is never better acquainted with a substance, than when he is able to decompose it, and to reproduce it from a combination of its parts, so the anatomist is well acquainted with the body of man, only, when having studied separately, and with the greatest care, each of his organs and each of the systems, formed by the collection of a certain number of similar organs, he is able to assign to each of them its place, to determine its relations, and the proportions which it bears in the structure of any one of our limbs. The study of the latter is much more difficult and extensive, than that of the former: for, the chemist who decomposes and recompounds a well-known substance, phosphate of lime, for instance, attains only to the knowledge of its constituent principles, and respective proportions: the phenomena of situation altogether escape him. The anatomist, on the other hand, who knows that such a part is composed of bones, of muscles, of nerves, of vessels, must know, not only every one of these parts, their relative bulk, but the exact place in which they are to be found.

Anatomy, pursued in this spirit, offers a field of wide extent: it is the art which Leibnitz called the analysis of situation, *analysis situs;* and the knowledge of it is too important not to require a separate place, among the departments of medical knowledge. I will not pass over the motives that are alledged for combining anatomy and physiology in one course of instruction. Anatomy, confined to the mere description of the organs, is too dry and fatiguing: physiology throws over it interest and variety: it helps to ensure the attention of the hearers, who will retain more permanently, what they have listened to with pleasure. Would not one think that physiological details were, for an audience, what is contrived for a sick and froward child, in the honey that is rubbed on the edge of the cup, to disguise the bitterness of the draught that is to recal him to life? In combining two objects, of which one has no interest but that of usefulness, whilst the other is engaging as well, the attention will be not merely divided, but altogether distracted, and the mind of those who read or listen, will skim over dry details, to seize with avidity what furnishes more to its activity of intelligence. Anatomy is to physiology, what geography is to history. General considerations on the situation, the size, the form, the relations, the structure of organ, are an indispensable preparation to the perfect understanding of its functions: accordingly, you shall find much anatomy in physiological treatises, as you find much geographical detail in faithful historians.

I have said enough, I trust, to escape the reproach of not having filled my book with anatomical descriptions, from the multitude of excellent works we possess on the anatomy of the human body. Let us now enquire what relation physiology bears to Comparative Anatomy.

If a machine can be perfectly known, only after taking it to pieces, down to its simplest elements; if the mechanism of the whole actión is conceived, only by separately studying the action of each different part, Comparative Anatomy, by aid of which we can study, in the great chain which the animal kinds compose, the separate action of each organ, appretiate its absolute or relative importance, consider it, at first, insulated and reduced, so to speak, to its own powers, in order to determine what part it bears in the carrying on of a function; Comparative Anatomy is of absolute necessity to him who would make great progress in the knowlèdge of man: it may be looked upon as a sort of *analytic method,* by means of which we more completely attain to the knowledge of ourselves.

In order to conceive rightly the operations of the human intellect, and explain the generation of the faculties of the soul, metaphysicians have imagined a statue, into which they have infused a gradual animation, by investing it, one by one, with our organs of sensation. Now, Nature has realized in some sort this dream of philosophy. There are animals to which she has entirely denied the organs of sight and hearing; in some, taste and smell seem to have no separate existence from touch; in others, she has exercised a sort of analysis on a system of parts which all concur in one function. It is thus, that in some animals, divesting the organ of hearing of the accessories allotted to collect, transmit, and modify the rays of sound, she has reduced it to a simple cavity, filled with a gelatinous fluid, in which float the extremities of the acoustic nerve, alone fitted to receive the impression of sound; a fact which overthrows all the hypotheses that had ascribed this sensation to other parts of the auditory apparatus.

Of all the physical sciences, Comparative Anatomy is that which furnishes the most useful facts to physiology. Like physiology, it is concerned with organized living beings: there is, therefore, no need of watching against the false applications, so often made from the sciences, whose objects are matter inorganic and dead, or which study, in living beings, only the general properties of matter. Haller was so well aware of the utility of introducing this science into physiology, that he has brought together the greater part of the facts known in his time, on the anatomy of animals, at the head of each chapter of his immortal work.

This general consideration of living and animated beings, so well adapted to unveiling the secret of our organization, has this further advantage, that it enlarges the sphere of ideas of him who applies to it. Let him who aspires to that largeness of conception, so requisite in medicine, where facts are so multiplied and various, explanations so contradictory, and rules of conduct so unfixed, cast a general glance on this great division of organized beings, of which many, in their physical structure, so nearly resemble man;—he will see the sovereign Architect of the world, distributing to all the element of life and activity, giving to some a less power of motion, to others more: so that, formed all on one model, they seem only the infinitely varied, but gradual shades of the same form, if forms have shades like colours: never passing abruptly from one to another, but rising or falling by gentle and due degrees; covering the interval that separates two different beings, with many species that serve as a transition* from one to the other, and which present a continuous series of advancement or degradation: organization being constantly simplified, in descending from man to the inferior creatures; but rising in complexity, in re-ascending from those animals to man, who is the most complex being in nature, and was justly considered, by ancient philosophy, as the master-piece of the Creator.

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* The conception is noble and interesting of a scale of being, which, as was said by C. Bonnet, connecting all the worlds, embracing all the spheres, should extend from the atom to the most exalted of cherubim. Without carrying it so high or so low, if we confine it to the natural beings with which we are well acquainted, and which can be brought under observation, it will be seen, that the idea is not so chimerical as some writers of most respectable authority have supposed it. The plan traced by C. Bonnet is evidently defective; we find in it beings set beside each other, that have but faint lines of resemblance, or altogether illusive. The present state of the natural sciences would allow of its being better done: one might try at least for all bodies what Jussieu has executed with regard to vegetable productions; and if this undertaking, in the hands of men the most able to bring it to a successful termination, left any thing defective, would not that imperfection be an indication of the existence of other worlds, or of lands yet unknown on the globe we inhabit; undiscovered regions,

If the intimate structure of our organs totally eludes our investigation, it is, that the finest and most delicate of their constituent parts are of such minute dimensions, that our senses have no hold on them. It is then well to have recourse to analogy, and to study the organization of animals that exhibit the same organs on a larger scale. Thus, the cellular texture of the lungs, which cannot be distinctly shewn in man, on account of the extreme minuteness of the smallest bronchiæ, may be satisfactorily seen in the vesicular lungs of salamanders and frogs. In like manner, the scales which cover the bodies of fishes and reptiles, or the legs of birds, give us a just idea of the structure of the epidermis, and of the arrangement of its small scales, which lie over each other, in a part of their surface.

The human structure being more complicated, must produce effects more numerous, and results more varied, and more difficult to understand. In commencing the study of the animal organization by that of man, we do not, therefore, follow the analytic method, we do not proceed from what is simple, to what is more complex. It would perhaps be an easier and a more natural way of arriving at a solution of the grand and difficult problem of the animal ecocomy, to begin by explaining its most simple terms; to rise by degrees from plants to vegetating animals, as polypi; from these to white-blooded animals, then to fishes and reptiles; from the latter to warm-blooded animals, and lastly to man himself, placed at the head of that long series of beings whose existence becomes complicated, in proporton as they approach him.

The study of every part of natural history, and especially of comparative anatomy, cannot fail, therefore, to prove of infinite advantage to the physiologist; a truth well expressed by the

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where those animals, and plants, and minerals would be found which were wanting to fill up the gaps in the immense series of co-ordinate existence?

Demonstratum fuit et hoc, nullam rem contrarias, vel omnino multùm differentes qualitates recipere posse, nisi per media prius iter fecerit.

GALENUS, *de Usu partium*, lib. 4, cap. 12.

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eloquent M. de Buffon*, who says, that if there existed no animals, the nature of man would be still more incomprehensible.

I shall say nothing of the well known relations of physiology to medical science, of which it is justly considered as the base or support. Medicine, called by some the art of healing, by others more properly, the art of treating diseases, may be defined the art of preserving health, of curing diseases, or of rendering them more supportable; medicine, in all its parts, is enlightened by physiology, and cannot have a surer guide. Owing to a neglect of this auspicious guide, therapeutics and materia medica long remained involved in a mist of conjectures and hypothesis. Physicians should never for a moment forget, that as a great number† of diseases consist in a derangement of the vital functions, all their efforts should tend to bring back sensibility and contractility to their natural condition; that the best classification of diseases and of medicines, is that which is founded on a judicious distinction of the vital powers. With this view it is that M. Alibert, in his elements of materia medica, classes medicines according to their effects on sensibility or contractility, and according to the organs on which their action is particularly exerted.

§ XII. CLASSIFICATION OF THE VITAL FUNCTIONS.

After having treated separately of the vital powers or faculties, nothing is easier than to arrange, in a clear and methodical order, the functions carried on by the organs which these powers call into action. The term *function* might be defined, *means of existence*. This definition would be the more just, as life is only the exercise of these functions, and as it ceases, when any one of the more important can no longer be carried on. From not distinguishing the faculties, from the functions which are merely the acts of the faculties or powers, several modern divisions, though far preferable to the old classification of the functions into vital, animal and natural, are, nevertheless, deficient in accuracy and simplicity. Thus Vicq-d'Azyr in the classification of the phenomena of physiology, inserted in the discourse which he has prefixed to his work on Anatomy, mistakes the cause for the effect, and places sensibility and irritability among the functions, and commits another mistake, by ranking among the latter, ossification, which is but a peculiar mode of nutrition, belonging to parts of a hard structure.

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* Histoire nat. tom. V. 12mo. p. 241. Discours sur la nature des animaux.

† All diseases consist in *physical derangements*, as solutions of continuity, displacements, *organic alterations*, as polypi, aneurisms, and other affections resulting from organic affection and alteration of structure; *vital lesions*, as fevers, *ataxiæ*, adynamiæ, vesaniæ, &c. see *Nosographie Chirurgicale.*

The best method of classing the actions which are performed in the living human body is, doubtless, that by which they are distributed and arranged according to the object which they fulfil—Aristotle, Buffon, and especially Grimaud, have laid on that base the foundation of a method which we shall adopt, with the modifications which we are about to mention.

Aristotle and Buffon had observed, that among the acts of the living economy, some were common to all beings that have life, to plants and animals during sleep and in waking, while others seemed to belong exclusively to man, and to the animals which more or less resemble him. Of these two modes of existence, the one *vegetative*, the other *animal*, the former appeared to them the more essential, as being more diffused and consisting merely in the assimilation of nutritive molecules, in the nutrition absolutely necessary to the preservation of the living being*, who, as his substance is incessantly wasting, would soon cease to exist, if these continual losses were not always repaired by the act of nutrition.

Grimaud, Professor of Physiology at Montpellier, too soon lost to the science which he cultivated as a philosopher truly deserving that name, adopted this simple and luminous division, developed it better than had been done before him, and uniformly followed it in his lectures and in his works†. This division of the functions into *internal*, which he likewise calls *digestive*, and into external or loco-motive, lately brought forward under the name of *organic* and *animal*, the former of which terms is quite inaccurate and defective, since it leads to a belief, that the animal life or of relation is not confided to organs, and that their vital instruments are solely employed on internal life or of nutrition (*Motus assimilationis*, Bacon; *Blas alterativum* Vanhelmont): This distinction does not comprehend the whole of the phenomena, and does not embrace the sum of the functions which are performed in the animal economy. In fact, there are not found in the two great classes which it establishes, the acts by which animals and vegetables re-produce and perpetuate themselves, and immortalize the duration of their species. All the functions destined to the preservation of the species are not included; they merely relate to the functions subservient to the preservation of individuals.

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* *Nam anima* nutritiva *etiam aliis inest, et prima et maxima, communis facultas animæ, secundùm quam omnibus vivere inest.* Aristot., *de anim.* lib. 2. cap. 4.

† In his M. S. lectures on Physiology, he seems to feel a complacency in that division which he had in a manner appropriated to himself, by his happy illustrations of it, and by the changes which he had introduced into it. In every lecture, I might almost say in every page, he returns to this division, explains it, dilates, and comments upon it. " The functions," " says he," " may be " divided into two great classes; some are performed in the interior of the body " and exclusively belong to it; others take place outwardly and belong to exter- " nal objects, &c." The digestive power presides, in his opinion, over the *internal functions* whose object is *nutrition;* The loco-motive power directs the external functions. " It is by means of the organs of sense that the animal enlarges his existence, that he applies and distributes it on the surrounding

I have, therefore, thought it right to include under two general classes, in the first place, the functions which belong to the preservation of the species, functions without which man might exist, as we see in eunuchs, but without which the human species would soon perish, from a loss of the power of re-production. In laying down these two great divisions, I have merely considered the object and end which each function has to fulfil.

Among the functions which are employed in the preservation of the individual, some fulfil this office by assimilating to his own substance the food with which he is nourished; the others, by establishing, in a manner suited to his existence, his relations with the beings which surround him.

The functions destined to the preservation of the species, may likewise be divided into two classes. Those of the first class require the concourse of two sexes; they constitute generation, properly so called; those of the second order, exclusively belong to the female, who, after conception, is alone destined to bear, to nourish, to bring into the world, and suckle the new being, the result of conception.

The internal, assimilating, or nutritive functions concur in the same end, and all serve to the elaboration of the nutritive matter. The aliment once admitted into the body, is

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objects, that he takes cognizance of the qualities in those objects which concern him; it is by means of the muscles essentially obedient to the organs of sense, that he adapts himself to those objects, that he places himself in a manner suited to the mode of their activity, &c."

subjected to the action of the digestive organs, which separate its nutritive parts: the absorbents take it up and convey it into the mass of fluids; the circulatory system conveys it to all the parts of the body, makes it flow towards the organs; the lungs and the secretory glands supply it with certain elements, and deprive it of others, alter, modify, and animalize it; in fine, nutrition, which may be considered as the complement of the assimilating functions, whose object it is to provide for the maintenance and growth of the organs, applies to them this animalized substance, assimilated by successive acts, when it has become quite similar to them.

Several, however, of these functions, serve at once to preserve and to destroy. Absorption, which takes up extraneous molecules to be employed in the growth of the organs, takes up equally the organic molecules which are detached by motion, friction, heat, and all the other physical, chemical, and vital causes. The action of the heart and of the blood vessels sends these fragments, together with the parts truly recrementitious, towards the lungs, which, at the same time that they bring about a combination of the nutritive parts with the oxygen of the atmosphere, separate from the blood the materials which can no longer be employed in nourishing the organs; the same power sends them towards the secretory glands, which not only purify what is liquid, by separating from it, that which cannot without danger remain in the animal economy, but which likewise elaborate or prepare peculiar fluids, some of which are results of the act of nutrition, are employed in that act, and impart to the substances on which it is performed a certain degree of animalization (as to the bile and saliva), while the others seem to be intermediate states, which the nutritive particles of the food are obliged to undergo, before complete animalization; such are the serous fluids and the fat.

It might perhaps seem more in conformity to the order of nature, to have combined the account of respiration with that of the circulation, by treating of the course of the venous blood, after the action of the absorbent vessels, with which the veins have so much analogy.—Then to have treated of the phenomena of respiration, or of the conversion of the venous blood into arterial, and of the course, of the latter into all the parts of the body, by the action of the heart and arteries; but the advantage which would be obtained from a method so contrary to the common practice, which is to consider separately the functions of circulation and respiration, appeared to me too unimportant to justify its adoption.

The external or relative functions, equally connected by their common destination, connect the individual to every thing that surrounds him: the sensations, by warning him of the presence of objects which may be useful or injurious to him; motion, by enabling him to approach, or avoid such objects, according as he perceives relations of advantage or disadvantage, according as the opposite sensations of pain or pleasure result from his action on them, or from theirs on him. In fine, voice and speech give him communication with beings enjoying the same means of communication, and that without a necessity of motion. The brain is the principal organ of these functions, as the system of circulation is the centre of the assimilating functions. All the impressions received by the organs of sense, are transmitted to the brain, and from the brain, determinations arise, as well as the voluntary motions and the voice. The sanguineous system receives the molecules destined to nutrition, and those which are to be thrown out of the body. The sensitive and circulatory systems are the only systems provided with a centre (the brain and the heart), which extend to all parts of the body, by emanations originating from that organ, or terminating in it (the nerves, the arteries, and veins): and, as the motions and the voice depend on sensation, and are immediately connected with it as necessary consequences, so, respiration, secretion, and nutrition are, in a manner, but consequences of the circulation which distributes the blood to all the organs, in order that these may produce on it various changes which constitute respiration, secretion, and nutrition. They are, to anticipate what is to come hereafter, only different kinds of secretion that take place at the expence of the different principles contained in the blood.

The circulation which holds the functions of nutrition in a kind of dependence, subjects the brain, which is the principal organ of the external functions, to an influence still more immediate and indispensable. The muscular motions are not less under its influence. It is the first function that is apparent in the embryo, whose evolution it brings about; in natural death, of all the functions, it is the last to cease. These are many reasons which justify Haller, for having placed it in the first order, and for having begun by its history, his great work on physiology. I enter into this digression, only to expose the absurdity of the claims of some authors, who, because they have varied the methodical order of the functions, broken the series, or made the slightest changes, for example, by placing the history of the function of smell and taste before the account of the internal or nutritive functions, think they have totally changed the aspect of the science: pitiful sophists, who accumulate subtleties instead of facts and ideas.

In warm- and red-blooded animals, the nutritive functions, digestion, absorption, circulation, respiration, the secretions and digestion are performed as in man, and in that respect, there exist between them very slight differences; nay, in some animals, these functions are performed with much more energy—Thus several animals digest substances, on which our own organs produce no effect, and others (birds) have a more rapid circulation, a more active nutrition, and evolve more heat. But not one of them is as well provided with organs to keep up intercourse, as a living being, with the surrounding objects. In no one animal, are the senses possessed of the same degree of perfection; the eagle, whose sight is so piercing, has a very dull sense of touch, taste, and smell. The dog, whose smell is exquisite, has a very ordinary extent of sight; in him, the taste and touch are equally imperfect —His touch, in the perfection of which, no animal comes up to man, has not been improved in delicacy, at the expence of the other senses. The sight, the hearing, the taste and smell, preserve a great delicacy, when their sensibility has not been impaired, by injudicious or too frequent impressions. The sensitive centre is in no one better developed, and fitter to direct safely the use of the organs of motion. No other animal can articulate vocal sounds, so as to acquire speech.

This greater extension of life in man, from the number and perfection of his organs, makes him liable to many more diseases than the other animals. It is with the human body, as with those machines which become more liable to be deranged, by increasing the number of their wheels, with a view of obtaining more extensive or more varied effects.

All organized bodies are possessed of assimilating functions; but as assimilation requires means varying in number and power, according to the nature of the being which performs it, the series of assimilating phenomena commences in the plant by absorption, since it draws immediately from the earth, the juices which it is to appropriate to itself. Its absorbing system, at the same time performs the functions of a circulatory organ, or rather, the circulation does not exist in plants, and the direct and progressive motion of the sap which ascends from the root towards the branches, and sometimes in a retrograde course, from the branches towards the roots, cannot be compared to the circulation of the fluids which takes place in man, and in the animals which most resemble him, by means of a system of vessels which every moment bring back the fluids to the same spot, and convey them over the whole body, by making them describe a complete circle, frequently, even, a double rotation (animals with a single or double circulation, that is, whose heart has one or two ventricles.) Plants breathe after their own manner, and produce a change in the atmospherical air, by depriving it of its carbonic acid gas, the result of combustion and of animal respiration, so that by a truly admirable reciprocity, plants, which decompose carbonic acid and allow oxygen to exhale, continually purify the air, which combustion and animal respiration are incessantly contaminating.

The functions preservative of the species are common to animals and plants. The organs by which these functions are performed, when compared in these two kingdoms of nature, offer a resemblance which has struck all naturalists, and has led them to observe, that of all the acts of vegetable life, no one is more analogous to the animal economy, than that by which fecundation is effected.

We shall not here explain the general characters of the two orders of functions which are subservient to the preservation of the species: the differences which belong to them are pointed out in several parts of this work.* I shall merely observe with the authors who have considered them generally, that they are in an inverse ratio to each other, so that, in proportion as the activity of the assimilating functions increases, that of the external functions is abated. Grimaud has, in the most complete manner, illustrated this idea of the constant opposition which exists between those two series of actions, over which, in the opinion of that physician, there preside two powers which he calls locomotive and digestive. It is in no kind of animals more distinct than in the carnivorous, which possess organs of sense of the greatest delicacy, together with muscles capable of prodigious efforts, and yet powers of assimilation so feeble, that their food cannot be digested, unless it be composed of materials analogous in composition to their own organs*.

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* Especially in the account of living beings, § V. of the preliminary discourse; articles *sleep* and *fetus*. It is impossible at present to go over all these distinctions, without entering into useless and disagreeable repetitions.

Too much importance should not be attached to this classification, like all other divisions, it is purely hypothetical. All is connected together, all is co-ordinate in the animal economy; the functions are linked together, and depend on one another, and are performed simultaneously; all represent a circle of which it is not possible to mark the beginning or the end. *In circulum abeunt* (Hippocrates). In man, while awake, digestion, absorption, circulation, respiration, secretion, nutrition, sensation, motion, voice, and even generation, may be performed at the same time; but, whoever in the study of the animal economy should bestow his attention on this simultaneous exertion of the functions, would acquire but a very confused knowledge of them†.

By becoming familiar with these abstractions, one might soon mistake them for realities; one might even go the length of seeing two distinct lives in the same individual; one would be apt to assign as the character of internal life, that it is carried on by organs independent of the will. Although this faculty of the soul presides over the phenomena of respiration, of mastication, of the expulsion of the urine and fæces, one might consider life as intrusted to *unsymmetrical* organs, although the heart, the lungs, and the kidneys, are evidently symmetrical; one might fancy it to exist in the fœtus, which neither breathes, nor digests, &c. Nothing in the animal economy, said Galen, is ruled by invariable laws, or can be subject to the same accurate results and calculations, as an inanimate machine (*Nil est in corpore viventi planè sincerum.* GALEN). Thus, respiration, which connects the external and assimilating functions, furnishes the blood with the principle which is to keep up the action of the brain, and to excite muscular contractions.—On the other hand, the motion of the muscles is of use in the distribution of the humours, and concurs in the phenomena of assimilation. The brain, by means of the eighth pair of nerves, holds influence over the stomach. The sensations of taste and smell seem to preside, in an especial manner, over the choice of food and of air, and to belong rather to the digestive and respiratory functions, than to those of the intellect or of thought.

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* In carnivorous animals, the power of digestion is exceedingly weak; but their muscles are very powerful. This relative force of the muscles was necessary in carnivorous animals, as they live by depredations and slaughter, as their instinct, in unison with their organization, sets them constantly at war with every thing that has life, and as their subsistence depends on their being victorious in the battles to which Nature incessantly calls them.

GRIMAUD, *first Memoir on Nutrition.*

† The division which I lay down, is not to be strictly adopted, and as being absolutely true. It is a mere hypothesis to be attended to, only in so far as it assists in arranging one's ideas in a more orderly manner. For, every arrangement, even when arbitrary, is useful in laying before us a great number of ideas, and in thereby facilitating the comparison that is to be instituted among them. All the acts of Nature are so connected, and are linked together in so close an union, and she passes from the one to the other, by such uniform motions, and by gradations so insensible and so adjusted, as to leave no space for us to lay down the lines of separation, or demarcation, which we may choose to draw. All our methods of classing and arranging the productions of nature, are mere abstractions of the mind, which does not consider things as they really are, but which attends to certain qualities, and neglects or rejects all the rest.

GRIMAUD, *Lectures on Physiology.*

We have seen in this kind of general introduction to the study of physiology, what idea is to be formed of that science as well as of life, the study of which is its object; into how many classes the beings in nature may be divided, and into how many elements they are resolvable: what differences exist, between inorganized, and organized and living bodies, between plants and animals; how life is complicated, modified, and extended, in the immense series of beings which are endowed with it, from the plant to man; and in further particularizing the object under our consideration, we have examined, what are the organs which, by their union, form the human machine; what powers govern the exercise of their functions: Then, we have laid down the fundamental laws of sensibility and contractility, we have spoken of sympathies and habits, of the internal nervous apparatus, which unites, collects, and systematizes the organs of the assimilating functions; we have endeavoured to determine from facts, the existence of the cause which subjects living beings to a set of laws very different from those which inorganic matter obeys. The knowledge of these laws, is the light which is to guide us in the application to physiology of the accessory sciences. Finally, in the arrangement of the objects which this science considers, I have adopted a more simple and natural division, than any hitherto employed.

I shall close this preliminary discourse, by saying a few words on the order adopted in the distribution of the chapters. I might have begun by a view of the external functions, as well as of those of assimilation or nutrition, of sensation, or of digestion. I have given precedence to the functions of assimilation, because of all others, they are the most essential to existence, and their exercise is never interrupted, from the instant in which the embryo begins to live, till death. In beginning with an account of them, we imitate nature therefore, who imparts to man this mode of existence, before she has connected him with outward objects, and who does not deprive him of it, until the organs of sense, of motion, and of the voice have completely ceased to act.

As to the course which has been followed in the arrangement of the functions that belong to the same order, or which concur in the same end, it was too well laid down by nature, to allow us to depart from it. I have thought it right, that the consideration of the voice should immediately precede that of generation, in order that the arrangement might, at a glance, shew the connexion which exists between their phenomena. Several animals use their voice, only during the season of love; the birds which sing at all times, have, during that period, a more powerful and sonorous voice. When man becomes capable of reproduction, his vocal organs suddenly become evolved, as though nature had wished to inform him, that it is through them he is to express his desires to the gentle being who may sympathize in them. The voice, therefore, serves as a natural connexion, between the external functions, and those which are employed in the preservation of the human species.

The voice, which leads so naturally from the functions which establish our external relations, to those whose end is the preservation of the species, is still more intimately connected with motion. It is, in a manner, the complement of the phenomena of locomotion; by means of it, our communication with external objects is rendered easier, more prompt, and more extensive: it depends on muscular action, and is the result of voluntary motion. Finally, these motions sometimes supply the place of speech, in pantomime, for example, and in the greater number of cases, the language of action concurs in adding to its effect. Every thing, therefore, justifies me in placing this function after motion, in separating it from respiration, with which every other author has joined it, without considering that the relation between the voice and respiration is purely anatomical, and can, therefore, in no wise apply to physiology.

I have placed after generation, an abridged account of life and death, in which will be found, whatever did not belong to any of the preceding divisions. The necessity of this appendix, containing the history of the different periods of life, that of the temperaments and varieties of the human species, that of death and putrefaction, arises from the impossibility of introducing into the particular history of the functions, these general phenomena in which they all participate.

FIRST CLASS.

LIFE OF THE INDIVIDUAL.

FIRST ORDER.

FUNCTIONS OF ASSIMILATION,

Or, Functions which are subservient to the preservation of
the Individual, by assimilating to his substance, the food
by which he is nourished.

NEW ELEMENTS
OF
PHYSIOLOGY.

CHAPTER I.

OF DIGESTION.

I. Digestion is a function common to all animals, by which substances extraneous to them, are introduced into their body, and subjected to the action of a peculiar system of organs, their qualities altered, and a new compound formed, fitted to their nourishment and growth.

II. *General considerations on the Digestive organs.* Animals alone are provided with organs of digestion; all of them, from man down to the polypus, contain an alimentary cavity variously shaped. The existence of a digestive apparatus may, therefore, be taken as the essential characteristic of the animal kind. In man, this apparatus consists of a long tube extending from the mouth to the anus: within this canal, there empty themselves the excretory ducts of several neighbouring glands, that secrete fluids fit for changing, for liquefying, and animalizing the alimentary substance. The different parts of this digestive tube are not of equal capacity; at first, enlarged in the part which forms the mouth and pharynx, it becomes narrower in the œsophagus; this last, dilating considerably, forms the stomach, which again contracting, is continued down under the name of intestine. This tube itself varies in size in different parts of its extent; and it is by the consideration of these differences of size, that anatomists have principally been guided in their divisions.

The length of the digestive tube is from five to six times the length of the whole body, in an adult: it is greater in proportion in a child. At this age, likewise, digestion is more active, and proportioned to the necessities of growth in the individual. The digestive cavity is in man open at both extremities; in some animals, in the zoophyte for example, one opening serves the purpose of mouth and of anus, receives the food and ejects the excrementitious remains.

The extent of the digestive canal is according to the nature of the aliments on which the animals feed: the less those aliments are analogous in their nature, to the substance of the animal which they are to nourish, the longer must they remain in his body to undergo the necessary changes. Therefore, is is observed, that the intestine of graminivorous animals is very long, their stomach very capacious and often complex, while carnivorous animals have their intestinal canal short and strait, and so arranged, that the animal substances which are most nourishing, in least bulk, of easy and rapid digestion, which, by too long a stay in the intestines, might become putrid, pass readily through it. In this respect, man holds a middle station between those animals which feed on vegetables, and those which feed on animal substances. He is, therefore, equally fitted for these two kinds of food; he is neither exclusively herbivorous, nor carnivorous, but omnivorous or *polyphagous*. This question, of such easy solution, has long employed physicians, naturalists, and philosophers; each bringing, in favour of his opinion, very plausible arguments, drawn from the form and number of the teeth, from the length of the intestinal canal, from the force of its parieties, &c.

The parietes of the digestive tube are essentially muscular; a mucous membrane lines its inside, forming within it various folds; lastly, a third coat is accidentally placed over the other two: and is furnished by the pleura to the œsophagus, by the peritoneum to the stomach, as well as to the intestinal canal.

The characteristic of this third coat is, that it does not cover the whole surface of the parts of the tube to which it is applied. The muscular coat may be considered as a long hollow muscle, extending from the mouth to the anus, and formed, throughout almost all the whole of its length, by two layers of fibres, the one set longitudinal, the other circular. The will directs the motions of the two extremities, while the rest of its course is not under its controul. In the cells of the tissue which unites its surfaces to the other coats, fat never accumulates, which might have impeded its contractions, and straitened and even obliterated the tube along which the food was to pass.

III. *Of Food, solid and liquid.* The aliments which nourish man, are obtained from vegetables or from animals. The mineral kingdom furnishes only condiments, medicinal substances or poisons.

By aliment is meant whatever substance affords nutrition, or whatever is capable of being acted upon by the organs of digestion. Substances which resist the digestive action, those which the gastric juice cannot sheathe, whose asperities it cannot soften down, whose nature it cannot change, possess, to a certain degree, the power of disturbing the action of the digestive tube, which revolts from whatever it cannot overcome: there is no essential difference between a medicinal substance and a poison. Our most active remedies are obtained from among the poisonous substances: tartar emetic, corrosive sublimate, opium, all of them remedies of so much efficacy in skilful hands, when administered unseasonably or in too strong doses, act as most violent poisons; they forcibly resist the digestive powers and furnish them nothing to be acted upon, while mild and inert substances yield to these powers, and come under the class of aliments. What then is to be thought of our ptisans, of chicken and veal broth, and other such remedies? That they are employed to deceive the hunger and thirst of the patient, to prevent his receiving into his stomach, substances whose laborious digestion would take up the strength required for the cure of the disease; that they are mere precautions of regimen, that he who most varies this kind of resource, can only be said to adopt a treatment of expectation, leaving to nature alone, the care of exciting those salutary motions which are to bring about a cure. Why do certain vegetable purgatives, as manna and tamarinds, produce so little effect, even though given in large doses? Because these substances contain many nutritious particles capable of being assimilated, so that strong constitutions digest them and completely neutralize their irritating or purgative qualities. An animal or vegetable substance, though essentially nutritious, may act as a medicine, or even as a poison, when, in consequence of the extreme debility of the digestive tube, or because it has not been sufficiently divided by the organs of mastication, it resists the digestive action. Thus surfeits are brought on, because the stomach is debilitated, because it is oppressed by too great a mass of substances, or because having been imperfectly triturated, they are insoluble. It is on considerations of this kind, that the true foundations of materia medica are laid.

Mineral substances are of a nature too heterogeneous to our own, to admit of being converted into our substance. It appears that their elements require the elaboration of vegetable life; hence, it has been justly observed, that plants are laboratories in which nature prepares the food of animals.

Aliments obtained from plants are less nutritious than those furnished by the animal kingdom, because in a given bulk, they contain fewer parts that can be assimiliated to our own substance. Of all the parts of vegetables, the most nourishing is their amylaceous fecula, but it yields the more readily to the action of the digestive organs, from having already experienced an incipient fermentation; on that account, leavened bread is the best of vegetable aliments. The flesh of young animals is less nourishing than that of the full-grown, although, at an early age, the flesh of the former abounds more in gelatinous juices; for, this abundant gelatine wants the necessary degree of consistence.

However various our aliments may be, the action of our organs always separates from them the same nutritious principles; in fact, whether we live exclusively on animal or vegetable substances, the internal composition of our organs does not alter; an evident proof, that the substance which we obtain from aliments, to incorporate with our own, is always the same, and this affords an explanation of saying of the father of physic. "There is but one food, but there exist several forms of food."

Attempts have been made to ascertain the nature of this alimentary principle, common to all nutritive substances, and it is conjectured, with some probability, that it must be analogous to gummy, mucilaginous, or saccharine substances; they are all formed from hydrogen and carbon, are well known to differ chemically, only in the different proportions of oxygen which they contain. Thus, sugar is a kind of gum, containing a considerable quantity of oxygen; and which is reduced, in a certain degree, to the state of starch, when brought to a very fine powder by means of a rasp, for, the friction disengaging a portion of its oxygen, deprives it in part of its flavour, and leaves it an insipid taste, similar to that of farinaceous substances. Nothing, in fact, nourishes better, more quickly, and from a smaller bulk, than substances of this kind. The Arab crosses the vast plains of the desert, and supports himself by swallowing a small quantity of gum arabic. The nourishing quality of animal and vegetable jellies is well known; saccharine substances soon cloy the appetite of those who are fondest of them. In decrepid old age, some persons live exclusively on sugar; I know several in that condition, who spend the day in chewing this substance, which is a laborious employment for their feeble and toothless jaws. Lastly, milk, the sole nourishment of the early periods of life, contains a great proportion of gelatinous and saccharine matter.

Though man, destined to live in all latitudes, is formed to subsist on all kinds of food, it has been observed, that the inhabitants of warm climates generally prefer a vegetable diet. The Bramins in India, the inhabitants of the Canary Islands, and of the Brazils, &c. who live almost exclusively on herbs, grain, and roots, inhabit a climate, against the excessive heat of which they have to seek means of protection: now, the digestion of vegetables is attended with less heat and irritation. The philosophical or religious sects, by which the abstinence from animal food was considered as a meritorious act, were all instituted in warm climates. The school of Pythagoras flourished in Greece, and the anchorets, who, in the beginning of the Christian religion, peopled the solitudes of Thebais, could not have endured such long fastings, or supported themselves on dates and water, in a more severe climate. So that the monks that removed into different parts of Europe, were obliged to relax from the excessive severity of such a regimen, and yielded to the irresistible influence of the climate; the most austere came to add to vegetables, which formed the base of their food, eggs, butter, fish, and even water fowl. In books of casuistry, it may be seen, on what ridiculous grounds there was granted a dispensation in favour of plovers, of water hens, wild ducks, snipes, scoters, birds whose brown flesh, more animalized and more heating, ought to have been proscribed from the kitchen of monasteries, much more strictly than that of common poultry.

Consider what is the alimentary regimen of the different nations on the face of the earth, and you will see, that a vegetable diet is preferred by the inhabitants of warm countries: to them, sobriety is an easy virtue; it is a happy consequence of the climate. Northern nations, on the contrary, are voracious from instinct and necessity. They swallow enormous quantities of food, and prefer those substances which in digestion produce the most heat. Obliged to struggle incessantly again the action of cold, which tends to benumb the vital powers, to suspend every organic motion, their life is but a continual act of resistance to external influences. Let us not reproach them with their voracity, and their avidity for ardent spirits and fermented liquors. Those nations that inhabit the confines of the habitable world, in which man is scarcely able to withstand the severity of the climate, the inhabitants of Kamtschatka, the Samoiedes, live on fish, that in the heaps in which they are piled up, have already undergone a certain degree of putrefactive fermentation. Does not the use of a food so acrid and heating, that in our climate it would inevitably be attended with a febrile action, prove plainly the necessity of balancing, by a vigorous inward excitement, the debilitating influence of powers that are operating from without? The abuse of spirituous liquors is fatal to the European transported to the burning climate of the West Indies. The Russian drinks spirituous liquors with a sort of impunity, and lives on to an advanced age, amidst excesses under which an inhabitant of the south of Europe would sink.

This influence of climate affects alike the regimen of man in health, and that of man in sickness, and, it has been justly observed of medicine, that it ought to vary according to the places in which it is practised.—Barley ptisan, honey, and a few other substances, the greater part obtained from the vegetable kingdom, sufficed to Hippocrates in the treatment of diseases, his therapeutic treatment was, in almost every case, soothing and refreshing. Physicians, who practise in a climate such as that of Greece, may imitate this simplicity of the father of physic. Opium, bark, wine, spirits, aromatics, and the most active cordials are, on the other hand, the medicines suited to the inhabitants of the North. The English physicians use, freely and without risk, these medicines which elsewhere would be attended with the utmost danger.

Simple aqueous drinks promote digestion, by facilitating the solution of the solids; by serving as a vehicle to their divided parts; and when rendered active by saline or other substances, as spirituous liquors are by alcohol, they are further useful in stimulating the organs and exciting their action.

The least compound drinks are possessed, in different degrees, of this double property of dissolving solid aliments, and of stimulating the digestive organs. The purest water is rendered stimulating by the air, and by the salts which it contains, in different proportions; and, to the want of that stimulating quality, is to be attributed the difficult digestion of distilled water.

The drinks best suited to the wants of the animal economy, are those in which the stimulating principles are blended, in due proportions, with the water which holds them in solution. But almost all the fluids which we drink, contain a certain proportion of nutritious particles. Wine, for example, contains these nutritive particles in greater quantity, as it is the produce of a warmer climate, and as saccharine matter predominates in its composition. Thus, Spanish wines are in themselves nourishing, and are perhaps fitter to satisfy hunger than to allay thirst, while the acidulous Rhenish wines, which are merely thirst-allaying, scarcely contain any cordial quality. Between the two extremes are the French wines, which possess, in a nearly equal degree, the treble advantage of diluting the fluids, of stimulating the organs, and of furnishing to the animal economy materials of nutrition.

IV. *Of hunger and thirst.* By the words *hunger and thirst*, are meant two sensations, which warn us of the necessity of repairing the loss, which our body is continually undergoing from the action of the vital principle. Their nature, as is well observed by M. Gall, is not better known than that of thought. Let us endeavour to explain the phenomena by which they are attended.

The effects of a protracted abstinence are, a diminution of the weight of the body, a diminution which becomes sensible in the course of twenty-four hours; a wasting of the body, from the loss of fat, discoloration of the fluids, especially the blood, loss of strength, excessive sensibility, sleeplessness, with painful sensations in the epigastric region.

Death from inanition is most easily brought on, in those who are young and robust. Thus, the unfortunate father, whose horrible story has been related by Dante, condemned to die of hunger and shut up with his children in a dark dungeon, died the last, on the eighth day, after having witnessed, in the convulsions of rage and despair, the death of his four sons, unhappy victims of the most execrable vengeance ever recorded in the history of man. Haller has related, in his great work on physiology, several instances of prolonged abstinence; if we are to give credit to these accounts, some of which are deficient in the degree of authenticity required to warrant belief, persons have been known to pass eighteen months, two, three, four, five, six, seven, and even ten years, without taking any nourishment. In the memoirs of the Edinburgh Society, is found the history of a woman who lived on whey only, for fifty years. The subjects of these cases are mostly weak, infirm women, living in obscurity and inaction, and in whom life, nearly extinct, just shewed itself, in an almost insensible pulse, an unfrequent and indistinct respiration. It is a fact well worthy of observation, that the muscles and viscera of some of them when examined after death, shone with a light evidently phosphoric.* Can it be that phosphorus is the result of the lowest degree of animalization? It may be easily conceived that living, in a manner, on their own substance, the fluids in such persons, have been frequently subjected to the causes which produce assimilation and animalization, and have undergone the greatest alteration of which they are capable.

The proximate cause of hunger has by some been conceived to depend, on the friction of the nervous papillæ of the empty stomach on each other; by others, it has been imputed to the irritation produced on its parietes, by the accumulation of the gastric juice. It has been thought to depend on the lassitude attending the permanent contraction of the muscular fibres of the stomach; and on the compression and creasing of the nerves, during that permanent constriction; on the dragging down of the diaphragm by the liver and spleen, when the stomach and intestines being empty, cease to support those viscera: a dragging which is the greater, as a new mode of circulation takes place in the viscera, which are supplied with blood by the cæliac artery, and while the stomach receives less blood, the spleen and liver increase in weight and size, because their supply is increased.

Those who maintain, that hunger depends on the friction of the parietes of the stomach against each other, when brought together in an empty state, adduce the example of serpents, whose stomach is purely membranous, and who endure hunger a long time, while fowls whose powerful and muscular stomach is able to contract strongly on itself, endure it with difficulty. But to say nothing of the great difference of vitality, in the organs of a bird and of a reptile, the stomach which continues closing on itself as it is emptied, may contract to such a degree as scarcely to equal in size a small intestine, without its following, as a necessary consequence, that the parietes which are in contact should exert on each other any friction, on which the sensation of hunger may depend. In fact, the presence of food is necessary to determine an action of the parietes of the stomach, and as long as it is empty, there is nothing to call forth such action.

Those who think that hunger is mechanically produced by the weight of the spleen and liver that keeps pulling down the diaphragm, which the empty stomach no longer bears up, observe, that it may be appeased, for a time, by supporting the abdominal viscera by means of a wide girdle; that hunger ceases as soon as the stomach is full, before the food can have yielded to it any materials of nutrition. On this hypothesis, which is purely mechanical, as that which explains hunger by the irritation of the gastric juice, by the lassitude of the contracted muscles, by the compression of the nerves, how shall we explain the fact, that when the hour of a meal is over, hunger ceases for a time? Ought not hunger, on the contrary, to be considered as a nervous sensation which exists in the stomach, is communicated by sympathy to all the other parts, and keeping up an active and continuous excitement in the organ in which it is principally seated, determines into it the fluids from all parts. This phenomenon, like all those which depend on nervous influence, is governed by the laws of habit, by the influence of sleep, and of the passions of the mind, whose power is so great, that literary men, absorbed in meditation and thought, have been known entirely to forget that they required food. Every thing which awakens the sensibility of the stomach, in a direct or sympathetic manner, increases the appetite and occasions hunger. Thus, bulimia depends, sometimes, on the irritation of a tape worm in the organs of digestion. The application of cold to the skin, by increasing, from sympathy, the action of the stomach, has been known to occasion *fames canina*, of which several instances are related by Plutarch (Life of Brutus). Ardent spirits, and highly seasoned food, excite the appetite, even when the stomach is overfilled. Whatever, on the contrary, blunts or renders less acute the sensibility of the stomach, renders more endurable or suspends the sensation of hunger. Thus, we are told by travellers, that the Turkish dervises and the Indian faquirs, endure long fasts, because they are in the habit of using opium, and lull, in a manner, by this narcotic, the sensibility of the stomach. Tepid and relaxing drinks impair the appetite; the use of opiates suspends suddenly the action of the stomach.

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* *Nitidissima viscera sunt animalium fame enectorum, et argentei fibrarum fasciculi.*

HALLER, *Elem. Phys.* tom. VI. page 183.

V. *Of thirst.* The blood deprived of its serosity, by insensible perspiration and by internal exhalation, requires incessant dilution, by the admixture of aqueous parts, to lessen its acrimony; and as the serosity is incessantly exhausting itself, the necessity for repairing that loss is ever urgent. The calls of thirst are still more absolute than those of hunger, and it is much less patiently endured. If it be not satisfied, the blood, and the fluids which are formed from it, become more and more stimulating, from the concentration of the saline and other substances which they contain. The general irritation gives rise to an acute fever, with heat and parching of the fauces, which inflame and may even become gangrenous, as happens in some cases of hydrophobia. English sailors, who were becalmed, had exhausted all their stock of fresh water, and were at a distance from land; not a drop of rain had for a long while cooled the atmosphere: after having borne, for some time, the agonies of thirst, further increased by the use of salt provisions, they resolved to drink their own urine. This fluid, though very disgusting, allayed their thirst; but at the end of a few days, it became so thick and acrid, that they were incapable of swallowing a mouthful of it. Reduced to despair, they expected a speedy death, when they fell in with a ship which restored them to hope and life. Thirst is increased every time that the aqueous secretions are increased; thus, it becomes distressing to a dropsical patient, in whom the fluids are determined towards the seat of effusion. It is excessive in diabetes, and in proportion to the increased quantity of urine. In fever, it is increased, from the effect of perspiration, or because in some of these affections; for example, in bilious fevers, the blood seems to become more acrid. Hence the advantage of cooling, diluting, and refreshing drinks, administered copiously, with a view to correct the temporary acrimony occasioned by the absence of a great quantity of the serous parts of the blood, and to lessen the over excitement of a fluid become too stimulating.

The use of aqueous drink is not the most effectual method of allaying thirst. A traveller exposed to the scorching heat of summer, finds it advantageous to mix spirits to plain water, which alone does not stimulate sufficiently the mucous and salivary glands, whose secretion moistens the inside of the mouth and pharynx, and covers these surfaces with the substance best calculated to suspend, at least for a time, the erethism on which thirst appears to depend.

VI. *On mastication.* The organs employed in the mastication of the food, are the lips, the jaws, and the teeth with these are furnished: the muscles by which they are moved, and those which form the parietes of the mouth. The motions of the lips are extremely varied, and depend on the single or combined action of their muscles, by which the greater part of the face is covered, and which may be enumerated as follows:—Elevators of the upper lip (*caninus, incisivus, levatores communes labiorum and myrtiformes*). Depressors of the under lip (*triangularis labiorum, quadratus genæ*). Abductors (*buccinator, zygomaticus major and minor, platysma myoides*). Constrictors (*orbicularis oris*).

VII. The motions of the upper jaw are so confined, that some have denied that it has any motion; it nevertheless rises a little, when the lower jaw descends; but it is principally by the depression of the latter, that the mouth is opened. The muscles at the back of the neck, and that part of the digastric muscle nearest the mastoid process, produce a slight elevation of the upper jaw, which moves with the whole head, to the bones of which it is firmly united. This conexion of the upper jaw with the bones of the head, renders this jaw less moveable in man than in the greater number of animals, in which, freed from the enormous weight of the skull, it stretches out in front of that cavity, over the lower jaw. As we follow downwards the scale of animal existence, the motions of the upper jaw is seen to increase, the further we descend from the human species; it is equal to that of the lower jaw, in the reptiles and in several fishes; hence the enormous dimensions of the mouth of the crocodile and shark; hence serpents frequently swallow a prey of a bulk greater than their own, and would be suffocated, but for the power they possess, of suspending respiration for a long time, and of waiting patiently, till the gastric juice dissolves the food, as it is swallowed.

In the act of mastication, the upper jaw may be considered as an anvil, on which the lower jaw strikes as a moveable hammer, and the motions of the under jaw, the presure it exerts, and its efforts, would soon have disturbed the connexion of the different bones of which the face is formed, if this unsteady edifice, merely formed of bones, in juxta position, or united by sutures, were not supported, and did not transmit to the skull, the double effort which presses on it from below upwards, and pushes it out laterally. Six vertical columns, the ascending apophyses of the superior maxillary bones, the orbitar processes of the malar bones, and the vertical processes of the palate bones, support and transmit the effort which takes place in the first direction, while the zygomatic processes forcibly press the bones of the face against each other, and powerfully resist separation outwardly or laterably. The lower jaw falls by its own weight, when its elevators are relaxed; the external pterygoid muscles, and those attached to the os hyoides, complete this motion, the centre of which, is not in the articulation of the jaw to the temporal bones, but corresponds to a line that should cross the coronoid processes, a little above the angles of the jaw. It is around this axis, that, in falling, the lower jaw performs a motion of rotation, by which its condyles are turned forwards, while its angles are carried backwards. In children, the coronoid processes standing off at a smaller distance from the body of the bone, of which they have nearly the same direction, the centre of motion is always in the glenoid cavities, which the condyles never quit, however much the jaw may be depressed. By this arrangement, nature has guarded against dislocation, which would have been frequent at an early period of life, from crying, during which, the jaw is depressed beyond measure, or when not knowing the just proportion between the capacity of the mouth, and the size of the bodies they would put into it, children endeavour to introduce those which it cannot receive. The lower jaw forms a double bended lever of the third kind, in which the power, represented by the temporal, masseter and internal pterygoid muscles, lies between the fulcrum and the resistance, at a smaller or greater distance from the chin.

The mode of articulation of the jaw to the temporal bones, allows it only a motion upwards and downwards, in which the teeth of both jaws meet like the blades of scissars, and a lateral motion, in which the teeth glide on each other, producing a friction well calculated to grind the food, which in the first part of the act of mastication was torn or divided.

VIII. In carnivorous animals, the levator muscles of the under jaw, especially the temporals and masseters, are prodigiously large and powerful. In them, the coronoid processes, to which the temporal muscles are attached, are very prominent; the condyles are received into a very deep cavity; while in herbivorous animals, on the contrary, they are less strong and bulky, and the pterygoid muscles, by whose action the lateral or grinding motion is performed, are stronger and more marked. The glenoid cavities are also in them wide but shallow, so that they allow the condyles to move freely on their surface. The comparative power of the levator and abductor muscles of the lower jaw, may be easily appreciated, by viewing the temporal and zygomatic fossæ. Their depth is always in an inverse ratio, and proportioned to the bulk of the muscles which they contain. In carnivorous animals, the zygomatic arch, to which the masseter is attached, is depressed, and seems to have yielded to the effort of the muscle. In the point of view which we have just taken, man holds a middle station between carnivorous animals and those which feed on vegetable substances; nothing, however, determines his nature better than the composition of his dental arches.

IX. The small white and hard bones which form the dental arches, are not alike in all the animals whose jaws are furnished with them. All have not, as man, three kinds of teeth. The *laniary** teeth are not to be met with, in the numerous class of rodentia. Some are without *incisors;* the former appear more fitted to tear fibrous tissues which offer much resistance. In carnivorous animals, they are likewise very long, and bent like curved pincers. The grinders are principally employed in grinding substances previously divided by the laniary teeth, which tear them, or by the incisors, which, in meeting as the blades of scissars, fairly cut them through: the latter, of which each jaw contains four, acting only on bodies which present but a slight resistance, are placed at the extremity of the maxillary lever. The grinders are brought nearer to the fulcrum, and it is on them that the great stress of mastication rests. If we wish to crush a very hard substance, we instinctively place it between the last large grinders, and by thus shortening considerably the lever, between the resistance and the fulcrum, we improve on the lever of the third kind, which, though most employed in the animal economy, acts the most unfavourably. The laniary teeth have very long fangs, which lying deeply buried in the alveolar processes, give them a degree of firmness to enable them to act powerfully, without a a danger of being loosened from their situation.

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* After the example of several naturalists, I have thought it right to give that name to the canine teeth; in the first place, because their principal use being to lacerate or tear fibrous tissues, it is fit that they should have a name from their manner of acting on the food, as is the case with the incisors and molares; in the second place, because the word canine, may lead to an erroneous conception, by leading to a belief that this kind of tooth belongs only to one kind of carnivorous animals, while they are stronger and more distinct, in the lion, the tyger, &c.

Such an explanation is indispensable, at a period when every body aspires to the easy glory of introducing innovations in language. The invention of words is, however, in the opinion of a celebrated female writer, a decided symptom of barreness of ideas.

The teeth differ essentially from the other bones, by the acute sensibility with which they are endowed; 2dly, by the nerves which may be traced into them, while they seem to be wanting in every other part of the osseous system; 3dly, by the mode of distribution of the blood vessels: these penetrate into them at an aperture which is seen at the extremity of their root, and they expand in the mucous membrance contained in the tooth, and which forms the most essential part of the bone; 4thly, by their not undergoing any change from exposure to the air, a property which they owe to the enamel which covers them externally. It has been said, with justice, that Nature, in sheathing the tooth with this covering, has imitated the process of tempering, by means of which, we harden the edge of steel or iron tools.

The enamel which covers the teeth, preserves the substance of the bone exposed to the contact of the air, from the injurious effects, which would not fail to result, from direct exposure, and as enamel is much harder than bone, it enables the teeth to break the hardest bodies without injury. The concentrated acids soften this substance and occasion a painful affection of the teeth. The sensibility possessed by these bones, is seated in the mucous membrane which lines their inward cavity, through which are distributed the vessels and nerves, which enter by openings at their roots. This membrane is the seat of a great number of diseases, to which the teeth are subject. The enamel, incessantly worn by repeated friction, grows and repairs its waste. The alveolar processes which receive the fangs of the teeth, firmly embrace them, and all of them being exactly conical in form, every point of these small cavities, and not merely their lower part at which the nerves and vessels enter, supports the pressure which is applied to these bones. When from accidental causes, or in the progress of age, the teeth are gone, their alveoli contract, then disappear; the gums, a reddish and dense membranous substance, which connects the teeth to the sockets, harden and become callous over their thinned edges. Old men who have lost all their teeth, masticate but imperfectly, and this circumstance is one of the causes of their slow digestion, as the gastric juice acts with difficulty on food, whose particles are not sufficiently divided.

X. *Salivary solution.* The above mechanical trituration is not the only change which the food undergoes in the mouth. Subjected to the action of the organs of mastication, which overcome the force of cohesion of its molecules, it is at the same time imbued with the saliva. This fluid, secreted by the glands placed in the vicinity of the mouth, is poured, in considerable quantity, into that cavity during mastication.

The saliva is a transparent and viscous fluid, formed of about four parts of water and one of albumen, in which are dissolved, phosphates of soda, of lime, and of ammonia, as well as a small quantity of muriate of soda; like all other albuminous fluids, it froths when agitated, by absorbing oxygen, for which it appears to have a strong affinity. Its affinity for oxygen is such, that one may oxydize gold and silver, by triturating in saliva, thin leaves of those metals which are of such difficult oxydizement.

The irritation occasioned by the presence or the desire of food, excites the salivary glands, they swell and become so many *centres of fluxion*, towards which the humours flow abundantly. Bordeu first called the attention of physiologists, to the great quantity of nerves and vessels received by the parotid, maxillary and sublingual glands, from the carotid, maxillary and lingual arteries, from the portio dura of the seventh pair of nerves, from the lingual nerve of the fifth pair, which penetrate their substance, or pass over a portion of their surface. This great number of vessels and nerves is proportioned to the quantity of saliva which is secreted, and this is estimated at about six ounces during the average time of a meal. It flows in greater quantity, when the food that is used is acrid and stimulating: it mixes with the mucus, copiously secreted with the mucous, buccal, labial, palatine, and lingual glands, and with the serous fluid, exhaled by the exhalent arteries of the mouth. The saliva moistens, imbues, and dissolves the ball formed by the aliment, brings together its divided molecules, and produces on them the first change. There can be no doubt, that the saliva mixing with the food, by the motion of the jaws, absorbs oxygen and unites to the alimentary substances, a quantity of that gas fit to bring about the changes which they are ultimately destined to undergo.

XI. The muscular parietes of the mouth are, during mastications, in perpetual action. The tongue presses on the food, in every direction, and brings it under the teeth; the muscles of the cheek, especially the buccinator, against which the food is pressed, force it back again under the teeth, that it may be duly triturated. When the food has been sufficiently divided, and imbued with saliva, the tip of the tongue is carried to every part of the mouth, and the food is collected on its upper surface. The food having been thus completely gathered together, the tongue presses it against the roof of the mouth, and turning it tip upwards and backwards, at the same time that its base is depressed, there is offered to the food an inclined plane, over which the tongue presses it from before backwards, to make it clear the isthmus of the fauces, and to thrust it into the œsophagus. In this course of the food along the pharynx and into the œsophagus, consists deglutition, a function which is assisted by the co-operation of several organs whose mechanism is rather complicated.

XII. *Deglutition.* In the process of deglutition, the mouth closes by the approximation of both jaws; at the same time, the submaxillary muscles, the *digastrici*, the *genio-hyoidei*, the *mylo-hyoidei*, &c. elevate the larynx and pharynx, by drawing down the os hyoides towards the lower jaw, which is fixed by its levator muscles. The hyo-glossus muscle, at the same time that it elevates the os hyoides, depresses and carries backwards the base of the tongue. Then the epiglottis, situated between these two parts, which are brought together, is pushed downwards and backwards by the base of the tongue, which lays it over the opening of the larynx. The alimentary mass, pressed between the palate and the upper surface of the tongue, slides on the inclined plain formed by the latter, and pressed by its tip, which bends back, clears the isthmus of the fauces. The mucous substance which exudes from the surface of amygdalæ further facilitates the passage of the food. When the food has thus dropped into the pharynx, the larynx which had risen, and had come forward, and which in that motion had drawn the pharynx along with it, descends and falls backwards. This last organ, stimulated by the presence of the food, contracts, and would in part send it back in a retrograde direction, by the nasal fossæ, if the velum palati, elevated by the action of the levatores palati, stretched transversely by the tensores palati, was not applied to their posterior apertures, and towards the openings of the Eustachian tubes. Sometimes this obstacle is overcome, and the food returns, in part, by the nostrils. This happens, when during the act of deglutition, we attempt either to laugh or speak. At such times, the air, expelled from the lungs with a certain degree of force, elevates the epiglottis and meeting the alimentary mass, pushes it back towards the nostrils through which it is to pass.—The isthmus faucium is closed against the return of the food into the mouth, by the swelling of the base of the tongue, raised by the action of the constrictor isthmi faucium, and of the constrictor pharyngis superior, which are small muscles contained in the thickness of the pillars of the velum.

The alimentary mass is directed towards the œsophagus, and is thrust into that canal, by the peristaltic contractions of the pharynx, which may be considered as the narrow part of a funnel-like tube.

The solid food passes behind the aperture of the larynx, which is accurately covered over by the epiglottis. The liquids flow along the sides of that opening, along two channels easily distinguished. They are always of more difficult deglutition than the solids; the molecules of a fluid have an incessant tendency to separate from one another, and to prevent this separation, the organs are obliged to use greater exertion, and to embrace with more precision the substance that is swallowed. Thus, it is observed, in those cases in which deglutition is prevented by some organic affection of the œsophagus, that the patients, though they have the power of swallowing solid food, find it difficult to swallow a few drops of a liquid, and are tortured with thirst, though they have still the power of satisfying their hunger.

The deglutition of air and of gaseous substances, is still more difficult than that of liquids, because these elastic fluids are much less coercible, and it requires considerable practice, to transmit a mouthful of air into the stomach. M. Gosse, of Geneva, had acquired that power from repeated experience, and he made use of it to induce vomiting at pleasure, and by the application of that faculty to the interests of science, he ascertained the digestibility of the articles of food in most common use.

The food descends into the œsophagus, propelled by the contractions of that musculo-membranous duct, situated along the vertebral column, from the pharynx to the stomach, Mucus is secreted, in considerable quantity, by the membrane which lines the inner part of the œsophagus, it sheathes the substances which pass along it, and renders their passage more free. The longitudinal folds of the inner membrane, allow the œsophagus to dilate; nevertheless, when it is stretched beyond measure, severe pain is experienced, occasioned, no doubt, by the distention of the nervous plexuses, formed by the nerves of the eighth pair which embrace the œsophagus, as they course along its sides—I purposely avoid speaking of the weight of the food, as one of the causes which enable it to pass along the œsophagus. Although, in man as in quadrupeds, that weight is no obstacle to deglutition, it favours that function in so slight a degree, that the diminution of muscular contractility at the aproach of death, is sufficient, altogether to prevent it. The act of drinking is then attended with a noise of unfavourable omen. This noise consists in a gurgling of the fluid which has a tendency to get into the larynx, whose opening is not covered over by the epiglottis; and if it be insisted upon, that the patient shall swallow some ptisan, the deglutition of which is impracticable, it flows into the trachea, and the patient dies of suffocation.

XIII. *Of the abdomen.* Before inquiring any further into the phenomena of digestion, let us shortly attend to the cavity which contains its principal organs. The abdomen is almost intirely filled by the digestive apparatus, of which the urinary passages form a part; its size, the structure of its parietes, are evidently adapted to the functions of that apparatus. The capacity of the abdomen, exceeds that of the other two great cavities; its dimensions are not invariably fixed, as those of the skull, whose size is determined by the extent of its osseous and inelastic parietes. They are likewise more varying than those of the chest, because, the degree of dilatation, of which the latter is susceptible, is limited by the extent of motion, of which the ribs and sternum are capable. The abdomen, on the contrary, enlarges in a sort of indefinite manner, by the yielding of its soft and extensible parietes. In some cases of ascites, the abdomen has been known to contain as much as eighty pints of liquid, and yet death has not followed as a consequence of so enormous an accumulation; while in consequence of the delicate texture of the brain, of the exact fulness of the skull, and especially of the inflexibility of its parietes, the slightest effusions within that cavity, are attended with so much danger; while the collection of a few pints of fluid, within the chest, occasions suffocation. This vast capacity of the abdomen, capable of being easily increased, was required in a cavity whose viscera, for the most part hollow, and admitting of dilatation, contain substances varying in quantity, and from which are disengaged gases occupying a considerable space. What a difference is there not, in the capacity of the abdomen of animals, according to the quality of the food on which they feed! Compare the slender body of the tyger, of the leopard and of all carnivorous animals, with the heavy mass of the elephant, of the ox, and of all animals that wholly or principally live on animal food. In the child, who, for his growth and developement, digests a considerable quantity of food, the abdomen is much more capacious than in the adult or the old man. In the child, the ensiform cartilage is situated opposite to the body of the eighth or ninth dorsal vertebra. In old men, it descends to the tenth or even the eleventh, so that the capacity of the abdomen decreases with the want of food, and with the activity of digestion.

The internal organs of the body are incessantly called into action by different causes, and excited to different motions. The action of the arterial system tends to raise the cerebral mass, and to impart to it motions of elevation and depression. The motion of the ribs brings about the expansion and the compression of the pulmonary tissue; the heart, which adheres to the diaphragm, drawn down by that muscle, when it descends, strikes against the parietes of the chest, every time its ventricles contract. The abdominal viscera are not less agitated by the motions of respiration, they experience from the diaphragm and from the abdominal muscles a perpetual action and re-action, by means of which, the circulation of the fluids in their vessels is promoted, the course of the food in the alimentary canal is accelerated, the activity of digestion increased, and several excretions, as of the urine and fæces, performed.

XIV. *Of Digestion in the Stomach.* The food which is taken into the stomach, accumulates gradually within its cavity, and separates its parietes, which are always in contact with each other when it is empty. The stomach, in that mechanical distention by the food, yields without re-acting. It is not, however, absolutely passive; its parietes apply themselves, by a general contraction, by a kind of tonic motion to the food which lies within it, and to this action of the whole stomach, the ancients gave the name of *peristole.* As the stomach dilates, its great curvature is thrust forward, the two folds of the omentum recede from each other, receive it between them, and embrace its outer and dilated part. In man, the principal use of this fold of the peritoneum, appears to be to facilitate the dilatation of the stomach, which expands chiefly at its forepart, as may be observed by inflating it in a dead body. As this viscus becomes distended with air, the two folds of the omentum apply themselves to its surface, and if this membrane is pierced with a pin, at the distance of an inch from its great curvature, the pin is observed to get nearer to this curvature; but the upper portion of the omentum can alone be employed in this use, and the whole of this membranous fold is never entirely occupied by the stomach. Shall we say with Galen, that the omentum guards the intestines against cold, and preserves in them a gentle warmth, necessary to digestion; or shall we admit the opinion of those who maintain, that it answers the purpose of a fluid, filling up spaces, and lessening the effect of friction and pressure from the anterior parietes of the abdomen; or shall we assert with others, that the use of the omentum is to allow the blood to flow into it, when the stomach, in a state of contraction, is incapable of receiving it. May not the blood which flows so slowly in its long and slender vessels, acquire some oleaginous quality which renders it fitter to supply the materials of bile?

The stomach likewise stretches, though in a less distinct manner, towards its lesser curvature, and the laminæ of the gastro-hepatic omentum are separated from each other, as those of the omentum majus. Such is the utility of the gastro-hepatic omentum, which may be considered as a necessary result of the manner in which the peritoneum is disposed in relation to the viscera of the abdomen. This membrane, which extends from the stomach to the liver, so as to cover it, could not fill the space which separates those organs, were it not for a kind of membranous communication which connects them, and in which are contained the vessels and nerves, which, from the lesser curvature or the posterior edge of the stomach, course towards the concave surface of the liver. This gastro-hepatic epiploon, may besides, by the separation of the two laminæ of which it is formed, favour the dilatation of the hepatic vein, which is situated, as well as the vessels, the nerves and the excretory ducts of the liver, in the thickness of its right border.

The stomach has ever been considered as the principal organ of digestion, yet its function in that process is but secondary and preparatory: it is not in the stomach, that the principal and most essential phenomenon of digestion takes place, I mean the separation of the nutritive from the excrementitious part of the food. The food, when received into the stomach, is prepared for this separation which is soon to be performed, it becomes fluid, and undergoes a material alteration; it is converted into a soft and homogeneous paste, known under the name of chyme. What is the agent that brings about this change? or in other words, in what does digestion in the stomach consist?

As it is frequently necessary to clear a spot on which one means to build, we will bring forward and refute the hypotheses that have been successively broached, to explain the mechanism of digestion. They may be enumerated, as follows:—*concoction*, *fermentation*, *putrefaction*, *trituration*, and *maceration* of the food taken into the cavity of the stomach.

XV. The first of these opinions was that of the ancients and of the father of physic; but, by the term *concoction*, Hippocrates did not mean, a phenomenon similar to that which takes place, when food is put into a vessel and exposed to the influence of heat. The temperature of the stomach, which does not exceed that of the rest of the body (32 degrees of Reaumur's scale) would be insufficient. Cold-blooded animals digest equally with the warm-blooded, and, as Vanhelmont observes, febrile heat impairs instead of increasing the powers of digestion. In the language of the ancients, concoction means the alteration, the maturation, the animalization of alimentary substances, assimilated to our nature, by the changes which they undergo in the cavity of the stomach. It is, however, a verified fact, that the natural heat of the stomach promotes and facilitates those changes. The experiments of Spallanzani on artificial digestion, shew, that the gastric juice is not of more efficacy than plain water, in softening and dissolving alimentary substances, when the heat is below seven degrees (of Reaumur's scale); that its activity, on the contrary, is greatly increased when the heat is ten, twenty, thirty, or forty degrees above the freezing point. The digestion in the cold-blooded animals is, besides, slower than in the hot-blooded.

XVI. The abettors of the theory of fermentation admit, that the food taken into the stomach undergoes an inward and spontaneous motion, in virtue of which it forms new combinations; and as the process of fermentation is promoted, by adding, to the substance that is undergoing that change, a certain quantity of the same that has already undergone the process; some have supposed, that there continually exists in the stomach a leaven, formed, according to Vanhelmont, by a subtle acid, and consisting, in the opinion of others, of a small quantity of the food that remains from the former digestion. But, independently of the circumstance that the stomach empties itself completely, and presents no appearance of leaven, when examined a few hours after digestion, substances undergoing fermentation require to be kept perfectly at rest, whereas the food is exposed to the oscillatory circulations and to the peristaltic contractions of the stomach, and this viscus is shaken by the pulsations of the neighbouring arteries; it is besides kept in continual motion by the act of respiration. In fermentation, gases are either absorbed or extricated, neither of which circumstances takes place, when the stomach is not out of order.

It should, however, be stated, in support of the opinion that accounts for digestion on the principle of fermentation, that we can derive nourishment, only from substances capable of undergoing fermentation, and that the substances which have undergone the panary and saccharine fermentation, are more easily digested, and in less time. This imperceptible fermentation, if it really take place, must bear a greater analogy to these two last processes, to those which are called vinous and acetous fermentation; but no one can differ from it more than the putrid fermentation.

XVII. There have been physiologists, however, from the time of Plistonicus, the disciple of Praxagoras, who maintain, that digestion is, in fact, the consequence of putrefaction. But, not only is ammonia not disengaged during that process, but our digestive organs have the power, as will be seen presently, of retarding, or of suspending, the putrefaction of the substances which are submitted to their action. In serpents, which in consequence of the great power of dilatation of their œsophagus, and from the power of holding asunder their jaws, both of which are moveable nearly in an equal degree, frequently swallow larger animals than themselves, and take several days to digest them; that part of the animal which is exposed to the action of the stomach, is observed to be perfectly fresh, and dissolved to a certain extent, while the part which remains out, exhibits signs of incipient putrefaction. In fine, notwithstanding the heat and moisture of the stomach, the food does not remain in it long enough to allow putrefaction to come on, even though every thing else should favour that process. Animals which have by chance swallowed putrescent animal substances, either reject them by vomiting, or, as Spallanzani has observed in some birds, deprive them of their putridity.

XVIII. The system of fermentation was invented by the chemists; that of trituration, by the mechanical philosophers, who compare the changes which substances undergo in a mortar from the action of the pestle, to the changes which the food undergoes in the stomach. But how different is the triturating action of a pestle, which crushes a substance softer than itself against a resisting surface, to the gentle and peristaltic action of the fibres of the stomach, on the substances which it contains. Trituration, which is a mechanical effect, does not alter the nature of the substance exposed to its action; but the food is decomposed and no longer the same substance, after it has remained some time in the stomach. As this evidently absurd hypothesis has long been held in high estimation, it will not be improper to spend a little time in the refutation of the proofs which are adduced in its support.

The manner in which digestion is brought about in birds, whose stomach is muscular, and especially in the gallinaceous fowls, is the most specious argument adduced by the abettors of mechanical digestion. Those granivorous birds all have a double stomach, the first is called the crop, its sides are thin and almost entirely membranous; a fluid is abundantly effused on its inner surface, the seeds on which they feed get softened, and undergo a kind of preliminary maceration in the crop, after which they are more easily ground by the gizzard, which is a truly muscular stomach, that fulfills the office of organs of mastication, almost entirely deficient in that class of animals. The gizzard acts so powerfully, that it crushes the solid substances exposed to its action, reduces into dust balls of glass and crystal, flattens tubes of tin, breaks pieces of metal, and what is much more extraordinary, breaks with impunity the points of the sharpest needles and lancets. Its internal part is lined with a thick semicartilaginous membrane, incrusted with a number of small stones and gravel, taken in with the food of those birds. The turkey cock is, of all other fowls, that in which this structure is most apparent; besides the small pebbles which line its inner membrane, its cavity contains, almost in all cases, a number of them. The rubbing together of these hard substances, exposed along with the seeds among which they are mixed, to the action of the stomach, may assist in breaking them down. The pieces of iron and the pebbles which the ostrich swallows, some of which Valisnieri met with in the stomach of that bird, are destined to the same use. But this mechanical division which the gizzard performs in the absence of organs of mastication, does not constitute digestion; the food, softened and divided by the action of the crop and of the gizzard, passes into the duodenum, and exposed in that intestine to the action of the biliary juices, undergoes within it the changes most essential to the act of digestion.

The singular structure of the lobster's stomach is not more favourable to the hypothesis of trituration. In that crustaceous animal, the stomach is furnished with a real mandibular apparatus, destined to break down the food. There are found in it, besides, at certain times of the year, two roundish concretions, on each side, under its internal membrane. These concretions, improperly termed crabs' eyes, consist of carbonate of lime joined to a small quantity of gelatinous animal matter; they disappear, when, after the annual shedding of the shell, the external covering, at first membranous, becomes solid from the deposition of the calcareous matter of which they are formed.

The very great difference between the stomach of these animals and that of man, ought to have precluded every idea of comparing them together. Spallanzani has justly observed, that in regard to the muscular power of the parietes of the stomach, animals might be divided into three classes, the most numerous of which consists of those creatures, whose stomach is almost entirely membranous, and furnished with a muscular coat of very little thickness. In this class are contained, man, quadrupeds, birds of prey, reptiles, and fishes. Notwithstanding the weakness of that muscular coat, Pitcairn, by a misapplied calculation, has estimated its power at 12,951 pounds; he reckons at 248,335 pounds, that of the diaphragm and of the abdominal muscles which act on the stomach and compress it in the alternate motions of respiration. What does so exaggerated a calculation prove, except, as Garat observes, that this vain show of axioms, definitions, scholia, and corollaries with which works not belonging to mathematics have been disfigured, have served only to protect vague, confused, and false notions, under the cover of imposing and respected forms. One need only introduce one's hand into the abdomen of a living animal, or a finger into a wound of the stomach, to ascertain that the force of that viscus on its contents, does not exceed a few ounces.

XIX. The learned and indefatigable Haller thought, that the food was merely softened and diluted by the gastric juice. This maceration was, in his opinion, promoted and accelerated by the warmth of the part, by the incipient putrefaction, by the gentle but continual motions which the alimentary substance undergoes. Maceration, in time, overcomes the force of cohesion of the most solid substances; but by dilution it never changes their nature.—Haller rested on the experiments of Albinus, on the conversion of membranous tissues into mucilage, by protracted maceration.

In ruminating animals, the cavity of the stomach is divided into four parts, which open into one another, and of which the three first communicate with the œsophagus. When the grass, after imperfect trituration by the organs of mastication, whose power is inconsiderable, has reached the paunch, which is the first and largest of the four stomachs, it undergoes a real maceration, together with an incipient acid fermentation. The contractions of the stomach propel the food, in small quantities at a time, into the bonnet, which is smaller and more muscular than the paunch; it coils on itself, covers with mucus the already softened food, then forms it into a ball, which rises into the mouth, by a truly anti-peristaltic motion of the œsophagus. The alimentary bolus, after having been chewed over again by the animal, which seems to enjoy that process, descends along the œsophagus into the third stomach, called the manyplus, on account of the large and numerous folds of its inner membrane. From this cavity the food enters into the abomasum, in which the stomachic digestion is completed. Such is the mechanism of rumination, a function peculiar to animals that have four stomachs; they do not, however, ruminate at all periods of their life. The sucking lamb does not ruminate: the half digested milk does not pass along the paunch or the bonnet, which are useless, but at once descends into the third stomach. Some men have been capable of a kind of rumination; the alimentary ball, after descending into the stomach, shortly after rose into the mouth, to be there chewed a second time, and to be anew imbued with saliva. Conrad Peyer has made this morbid phenomenon the subject of a dissertation entitled, *Mericologia, sive de Ruminantibus.*

This fourfold division of the stomach, so favourable to Haller's theory, is observed only in ruminating animals. But though animals are in general monogastric, as man, that is, provided with only one stomach, this viscus offers a number of varieties, the most remarkable of which refer to the relative facility which the food meets, in remaining within its cavity. The insertion of the œsophagus is nearer to its left extremity, and the great fundus of that viscus is smaller, as animals feed more exclusively on flesh, which is a substance of remarkably easy decomposition, and not requiring for its digestion a long stay in the stomach. In herbivorous quadrupeds, which do not ruminate, this great fundus forms nearly one half, sometimes even the greater part of the stomach, as the œsophagus enters into it very near the pylorus. In some, as in the hog, the stomach is divided into two parts by a circular contraction. The food which is received into the great fundus of the stomach, may remain longer in that viscus, as this part of its cavity lies out of the course of the aliment.

XX. *Of the gastric juice.* Of all the organs, the stomach probably receives, in proportion to its bulk, the greatest number of blood vessels; in its membrano-muscular parietes, which are little more than the twelfth part of an inch in thickness, there is distributed the coronary artery of the stomach, entirely destined to that organ; the pyloric, the right gastro-epiploic, given off by the hepatic artery. The greater part of the blood, therefore, which passes from the aorta to the cæliac artery goes to the stomach, for, though, of the arteries into which that trunk is divided, the coronary of the stomach is the least, the arteries of the liver and spleen send to the stomach several pretty considerable branches, before entering the viscera to which they are more particularly allotted. One need only observe the great disproportion between the stomach and the quantity of blood which it receives, to conclude, that this fluid is not merely subservient to its nutritition, but is destined to furnish the materials of some secretion.

The secretion in question, is that of the gastric juice, which is most abundantly supplied by arterial exhalation, from the internal surface of the stomach; it is most active at the instant when the food received within its cavity, excites irritation, transforms it into a *centre of fluxion*, towards which the fluids flow from all directions. The state of fulness of the stomach, favours the afflux of the fluids into the vessels, as, in consequence of the extension of its parietes previously collapsed, the vessels are no longer bent and creased. The arteries of the stomach, of the spleen and liver, arising from a common trunk, it may be easily understood how, when the stomach is empty, little blood enters into it, in that state of contraction; how, at the same time, the spleen which is less compressed, and the liver, must receive a larger supply of blood, and again a smaller quantity, when the stomach is full.

The gastric juice, the result of arterial exhalation, mixes with the mucus poured out by the mucous follicles of the internal membrane of the stomach. This mixture renders it viscous and ropy like the saliva, to which in man, the gastric juice bears a great analogy. It is very difficult to obtain it pure, so as to analyze it, and even if by long fasting, the stomach should be deprived of the alimentary residue, which might affect its purity, one could not prevent its being mixed with a certain quantity of liquid bile, which always flows back through the pyloric orifice, turns yellow the inner surface of the stomach, in the neighbourhood of that orifice, and even imparts a certain degree of bitterness to the gastric juice. The passage of the bile from the duodenum into the stomach, cannot be looked upon as morbid; it occurs in the most perfect health, which has led to a well founded opinion, that a small quantity of the biliary fluid is a useful stimulus to the stomach. This opinion is confirmed by an observation of Vesalius, who relates, that he found the ductus communis choledochus, opening into the stomach, in the body of a convict noted for his voracious appetite. It is further confirmed by what is observed in birds of prey, in the pike, &c. who digest easily and with great rapidity, because the termination into the duodenum of the ductus communis choledochus, being very near to the pylorus, the bile easily ascends into the stomach, and is always found there in considerable quantity.

To obtain some of this gastric juice, it is necessary, either to open a living animal under the influence of hunger, or to oblige a night bird of prey, as an owl, to swallow small spunges fastened to a long thread. When the spunge has remained for a short time in the stomach, it is withdrawn soaked with gastric juice, of which the secretion has been promoted by its presence in the stomach.

The gastric juice, in its natural state, is neither acid nor alkaline; it does not turn red or green, vegetable blue colours. Its most remarkable quality is, its singularly powerful solvent faculty, the hardest bones cannot withstand its action; it acts on those on which the dog feeds; it combines with all their organized and gelatinous parts, reduces them to a calcareous residue, forming those excrementitious substances so absurdly called *album græcum*, by the older chemists. The solvent energy of the gastric juice, is in inverse ratio of the muscular strength of the parietes of the stomach, and in those animals in which the parietes of that viscus are very thin, and almost intirely membranous, it has most power and activity. In the numerous class of zoophytes, it alone suffices to effect decomposition of the food, always more prompt, when accompanied by warmth of the atmosphere, as was observed by du Trembley, in the polypi, which in summer, dissolve in twelve hours, what in colder weather it would take three days to digest. In the actinia, in the holothuria, the gastric juice destroys even the shells of the muscles which they swallow. Are we not all acquainted with the peculiar flavour of oysters, how much they tend to whet the appetite? this sensation depends less on the salt water contained in the shell, than on the gastric juice which acts on the tongue, which softens its tissue and quickens its sensibility. This mucous substance, when received into the stomach, promotes the digestion of the food which is afterwards taken into it, for, the oyster itself is very little nutritious, and is used rather as a condiment, than as affording nourishment.

The gastric juice not only pervades and dissolves the food received into the stomach, but it unites and intimately combines with it, completely alters its nature and changes its composition. The gastric juice acts, in a manner peculiar to itself, on the food exposed to its action, and far from inducing a beginning of putrefaction, suspends on the contrary and corrects putrescency. This antiseptic quality of the gastric juice, suggested the practice of moistening ulcers with it to accelerate their cure, and the experiments made at Geneva and in Italy, have, it is said, been fully successful. I have made similar experiments with saliva, which, there is every reason to consider, is very similar to the gastric juice, and I have seen old and foul ulcers assume a better appearance, the granulations become healthy, and the affection rapidly advance towards a cure, from the use of that irritating fluid. I had under my care an obstinate sore on the inner ankle of the left leg of an adult; notwithstanding the external application of powdered bark, and of compresses soaked in the most detergent fluids, this sore was improving very slowly, when I bethought myself of moistening it, every morning, with my saliva, the secretion of which was increased, by the hideous aspect of the sore. From that time, the patient evidently mended, and his wound contracting daily, at last became completely cicatrized.

However powerful the efficacy of the gastric juice, to dissolve the alimentary substances, it does not direct against the coats of the stomach its active solvent faculty. These parietes endowed with life, powerfully resist solution. The lumbrici so tender and delicate, for the same reason, can exist within it, without being in the least affected by it, and such is this power of vital resistance, that the polypus rejects unhurt its arms, when it happens to swallow them among its food.* But when the stomach and the other organs have lost their vitality, its parietes yield to the solvent power of the juices which it may contain, they become softened, and even in part destroyed, if we may believe Hunter, who found its inner membrane destroyed in several points in the body of a criminal, who for some time before his execution, had been prevailed upon, in consideration of a sum of money, to abstain from food.

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* It had been thought, that no animal could live on the flesh of its own kind, and this circumstance was explained on the same principle; but to refute it, we need only quote the instance of cannibals and of several tribes of carnivorous animals, who, in the absence of other prey, devour one another.

The gastric juice is capable, even after death, of dissolving food introduced into the stomach, by a wound made into it, provided the animal still preserves some degree of animal heat. It acts on vegetable and animal substances triturated and put into a small vessel, such as those under which Spallanzani, in his experiments on artificial digestion, kept up a moderate heat. Let us not however consider as the same, this solution of the food in the gastric juice, out of the stomach, and that which occurs in digestion within the organ. Every thing tends to shew, that the stomach ought not to be considered as a chemical vessel, in which there takes place a mixture giving rise to new combinations. The tying the nerves of the eighth pair, the use of narcotic and of opium, intense thought, every powerful affection of the mind, trouble or even entirely suspend digestion in the stomach, which cannot take place independently of nervous influence. Yet this nervous influence may possibly not concur directly, and of itself, to stomachic digestion; it is perhaps merely relative to the secretion of the gastric juice, which the ligature of the nerves, the action of narcotics or of other substances may impede, alter, or even completely suspend.

It is now pretty generally admitted, that digestion in the stomach, consists in the solution of the food in the gastric juice. This powerful solvent penetrates, in every direction, the alimentary mass, removes from one another, or divides its molecules, combines with it, alters its inward composition, and imparts to it qualities very different from those which it possessed before the mixture. If, in fact, a mouthful of wine or of food is rejected, a few minutes after being swallowed, the smell, the flavour, all the sensible and chemical qualities of such substances, are so completely altered, that they can scarcely be recognized; the vinous substances turned, to a certain degree, sour, are no longer capable of the acetous fermentation. The energy of the solvent power of the gastric juice, perhaps over-rated by some physiologists, is sufficient to dissolve and reduce into a pulp, the hardest bones on which some animals feed. It is highly probable, that its chemical composition varies at different times; that it is acid, alkaline or saponaceous, according to the nature of the food. Although the gastric juice be the most powerful agent of digestion, its solvent power requires to be aided by several secondary causes, as warmth, which seems to increase, and, in a manner, to concentrate itself in the epigastric region, as long as the stomach is engaged in digestion; a sort of inward fermentation which cannot be, strictly speaking, compared to the decomposition which substances, subject to putrefaction and acescency undergo. The gentle and peristaltic action of the muscular fibres of the stomach, which press, in every direction, on the alimentary substance, performs on it a slight trituration, while the moisture of the stomach softens and macerates the food, before it is dissolved; one might therefore say, that the process of digestion is at once chemical, mechanical, and vital; in that case, the authors of the theories that have been broached, have been wrong, only in ascribing to one cause, such as heat, fermentation, putrefaction, trituration, maceration, and the action of the gastric juice, a process which is the result of a concurrence of these causes united.

The food remains in the stomach, during a longer or shorter space of time, according as by its nature, it yields more or less readily to the changes which it has to undergo. Gosse of Geneva, ascertained, by experiments performed on himself, that the animal and vegetable fibre, concrete albumen, white and tendinons parts, paste containing fat or butter, substances which have either not undergone fermentation, or which do not readily undergo that process, remain longer in the stomach, offer more resistance to the gastric juice, than the gelatinous parts of animals or vegetables, fermented bread, &c.; that the latter required but an hour for their complete solution, while the former were scarcely dissolved, at the end of several hours.

XXI. The following case throws, methinks, some light on the mechanism and importance of the action of the stomach in digestion. The patient was a woman whom I had frequent opportunities of examining at the "hôpital de la Charitè" at Paris, in the clinical wards of Professor Corvisart, in which she died on the 9th nivose of the year X. after six months' stay in the hospital.

A fistulous opening, of an oval form, an inch and a half in length, and upwards of an inch in breadth, situated at the lower part of the chest, at the upper and left side of the epigastric region, afforded an opportunity of viewing the inner part of the stomach, which when empty of food, appeared of a vermilion colour, was

was covered with mucus, its surface wrinkled over with folds about half an inch deep, and enabled one to distinguish the vermicular undulations of these folds, and of all the parts which were in sight. The patient, who was then forty-seven years of age, had had this fistula since she was in her thirty-eighth year. Eighteen years before, she had fallen on the threshhold of a door, the blow had struck against her epigastric region. The place remained affected with pain, and she became incapable of walking or of sitting, otherwise than bent forward and to the left side. At the end of this long interval, a phlegmonous and oblong tumour appeared on the injured spot; during the nausea and vomiting which came afterwards, the tumour broke, and there escaped at the wound, which was left by this rupture, two pints of a fluid which the patient had just swallowed to obtain relief. From that time, the fistula, which at first, would scarcely have admitted the tip of the little finger, increased daily; at first it allowed only the fluids to pass, but, on the eighth day, the solid food came away freely, and continued to do so till she died. When admitted into the hospital, she ate as much as three women of her age, she voided about a pint of urine and went to stool, only once in three days. Her fæces were yellowish, dry, rounded, and weighed more than a pound. Her pulse was very feeble and extremely slow, its pulsation scarcely exceeding forty-five or forty-six beats in a minute. Three or four hours after a meal, an irresistible desire obliged her to take off the lint and compresses with which she covered the fistulous opening, and to give vent to the food which her stomach might happen to contain; it came out rapidly, and there escaped at the same time, and with a noise, a certain quantity of gases. The food thus evacuated, exhaled an insipid smell, was neither acid nor alkaline, for, the chymous and grayish coloured pulp into which they were reduced, when suspended in a certain quantity of distilled water, did not affect vegetable blues. The digestion of the food was far from being always complete, sometimes, however, the smell of wine could not be recognized, and the bread formed a viscid, thick and soft substance, pretty similar to fibrine newly precipitated by the acetous acid, and it floated in a tenacious liquid of the colour of common broth.

It follows, from the experiments performed at the Ecole de Médicine, on these half digested substances, and on the same before their admission into the stomach, that the changes which they undergo, consist in the increase of gelatine, in the formation of a substance which has the appearance of fibrine, without having all its qualities, in a greater proportion of muriate and phosphate of soda, as well as of phosphate of lime.

This patient was unable to sleep, till she had emptied her stomach, which she cleared by swallowing a pint of infusion of chamomile. In the morning, there was seen in the empty stomach, a small quantity of a ropy frothy fluid, like saliva. It did not turn vegetable blues, to a green or red colour, was not homogeneous, but exhibited particles, of some degree of consistence, among the more fluid parts, and even albuminous flakes completely opaque. The experiments performed on this fluid, shewed that it bore a considerable analogy to saliva, which, however, is rather more liable to putrefaction.

The vermicular motion by which the stomach cleared itself of its contents, took place in two different, but not in opposite directions, the one pressing the food towards the fistulous opening, the other towards the pylorus, through which the smaller quantity was allowed to pass.

On opening the body, it was found, that the fistula extended from the cartilage of the seventh left rib, as high as the osseous termination of the sixth; its edges were rounded and from three to four lines in thickness; they were covered with a thin moist skin, of a red colour, and similar to that of the lips. The peritoneal coat of the stomach, adhered so firmly to the peritoneum lining the fore part of the abdomen, around the opening, that the line of adhesion would not be observed. The opening was in tho anterior part of the stomach, at the union of the two-thirds on the left side, with the third on the right of that viscus; that is, about eight fingers' breadths from its greater extremity, and only four from the pylorus. It extended from the greater to the lesser curvature. In other respects, it was the only organic affection of that viscus.

It should be stated, that for several years, the patient had been thin and emaciated, and had led a languid life, which was terminated by a colliquative diarrhœa. She seemed to be supported, only by the small quantity of food which passed through the pylorus, into the duodenum, where it received the influence of the bile, whose action on the chyme, is, as we shall presently state, absolutely essential to the separation of the nutritious parts. Not that there was any thing to prevent the absorbents of the stomach from taking up a certain quantity of nutritious particles, but that small quantity of food, in an imperfect condition, was of very little service in imparting nourishment, and, in that respect, she was in similar circumstances to patients who are affected with obstruction of the pylorus, and reject the greater part of their food, when, digestion being over, this contracted opening can no longer allow any food to pass.

XXII. While the alimentary solution is going on, the two openings of the stomach remain perfectly closed; no gas disengaged from the food, escapes along the œsophagus, except when digestion is imperfect. A slight shivering is felt, the pulse becomes quicker, and more contracted, the vital power seems to forsake the other organs, to concentrate itself on that which is the seat of the digestive process. The parietes of the stomach are soon called into action; its circular fibres contract in different points; these peristaltic oscillations, at first irregular and uncertain, acquire more regularity, and act from above downwards, and from the left to the right, that is to say, from the cardiac to the pyloric orifice. Besides, its longtitudinal fibres shorten it, in the direction of its greatest diameter, and bring nearer to each other its two orifices. In these different motions, the stomach rises over the pylorus, so that the angle which it forms with the duodenum, almost entirely ceases, and this facilitates the escape of the food. It has been observed, that during sleep, digestion takes place much more readily, when we lie on the right, than on the left side, and this circumstance has been ascribed to the compression of the liver on the stomach. It is much more likely to depend on the circumstance, that when we lie on the right side, the passage of the food is facilitated by its own weight, the natural obliquity of the stomach, from left to right, being increased, by the changes attending the presence of the food.

XXIII. *On the uses of the Pylorus.* The pyloric orifice is furnished with a muscular ring, covered over by a fold of the mucous membrane of the stomach. This kind of sphincter keeps it perfectly closed, while digestion is going on in the stomach, and will not allow a free passage to the food which has not yet undergone a sufficient change. The pylorus, which is endowed with a peculiar and delicate sensibility, may be considered as a vigilant guard, which prevents any thing from passing into the intestinal canal, till it has undergone the necessary changes. Several authors quoted by Haller, have, very justly, observed, that the alimentary substances do not leave the stomach, in the same order that they were received into it, but that they are evacuated according to their degrees of digestibility.

One may say, that there really takes place in the stomach, a sorting of the different substances which it contains. Those that are most readily dissolved, get near to the pylorus, which admits them, rejecting those which, not yet sufficiently digested, cannot produce on it the necessary affection. To this delicacy of *tact*, which I ascribe to the pylorus, will be objected, perhaps, the passage it allows to pieces of money and other foreign indigestible substances. But these bodies, which have always lain some time in the stomach, before theymake their way into the intestines, repeatedly attempt the orifice of the pylorus, and pass through, only when they have at last accustomed it to their contact. The gastric system is under the laws of a secretory gland: and as the roots of the excretory ducts, being endued with a sort of elective sensibility, will not receive the secreted fluid, until it has undergone the necessary preparation in the glandular parenchyma, in the same manner, the pylorus admits aliments and gives them passage into the intestines, which may be regarded as the excretory ducts of the stomach, only when they have been sufficiently elaborated by the action of this organ.

XXIV. As the stomach empties itself, the spasm of the skin goes off; the shivering is followed by a gentle warmth; the pulse increases in fulness and frequency; the insensible perspiration is augmented. Digestion brings on, therefore, a general action analogous to a febrile paroxysm; and this fever of digestion, noticed already by the ancients, is particularly observable in women of great sensibility. Nothing positive can be said on the duration of stomachic digestion; food passes sooner or slower from the stomach, according as its nature is such as to resist, more or less, the actions which tend to dissolve it; according too to the strength and vigour of the stomach at the time, and to the activity of the gastric juices. Yet we may state from three to four hours, as the mean time of their remaining there. It is of consequence to know the time required for digestion in the stomach, that we may not disturb it by baths, bleedings, &c. which would call off towards other organs, those powers which ought, at that time, to be concentrated upon the stomach.

If, as is indisputable, the stomach carries with it, into its action, all the other organs of the economy; if it summons to its aid, the so to say, the whole system of the vital powers; if this sort of derivation is the more conspicuous, as the organization is more delicate, the sensibility more lively, the susceptibility greater, the importance is apparent of enforcing a strict diet in acute diseases, and in all cases where Nature is engaged in an organic operation, which a little increase of irritation could not fail to disorder, or to break off. Those who have practised in great hospitals, know to how many patients indigestions are fatal. I have seen some with large ulcers; suppuration was copious and healthy; the granulations florid and all promising a happy issue, when ignorant friends bring them by stealth indigestible food, with which they cram themselves, in spite of the utmost watchfulness. The stomach, used to a mild and moderate regimen, at once overloaded with food, is changed into a *centre of fluxion*, towards which the juices and humours all tend, an irritation is produced beyond that on the ulcerated surface; which, in a little time, ceases to secrete pus, the fleshy granulation become flabby, extreme oppression is felt; with a difficulty of breathing comes on a pungent pain in the side, the pain sympathetically felt in the lungs, makes this organ the seat of an inflammatory and purulent congestion, a rattle ensues, and the patients die of suffocation, at the end of two or three days, sometimes in twenty-four hours; and this fatal termination is especially accelerated, when, as I have often witnessed, a blister is applied to the seat of the pain, instead of the ulcerated surface.

It will seem surprising, perhaps, that in the case of which I have just been speaking, it should be in the lungs, and not the stomach itself, that the congestion and the pain take place; but, besides that the most permeable organ of the body, is the lungs, as well as the weakest, and the most easily yielding to *fluxionary motion**, a host of instances prove, what a close sympathy unites it to the stomach. Let us but call to mind pleurisies and bilious peripneumonics, those acute pains of the side, which, since Stahl, physicians have so succesfully treated with vomits. The rapidity with which their symptoms go off, on the evacuation of the sordes which oppress the stomach, shews clearly that these sympathetic diseases are not owing to the metastasis of bile upon the lungs, and that they do not consist in the simultaneous existence of a gastric affection, and of an inflammatory state of the pleura or of the lungs, but that they are simple gastric affections, in which the lungs are, at the same time, the seat of a sympathetic pain.

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* Of all the organs it is that in which we most meet with organic injury: and those who have opened many bodies, may have observed, how rare it is to find the lungs completely sound in adults and in old men.

The action of the parietes of the stomach ceases, only when this viscus is completely cleared of the food it contained. The gastric juice, no longer secreted, ceases to be poured so freely by its arteries, and the parietes, which close upon each other, are chiefly lubricated by the mucus so plentifully secreted by the inner coat.

At times, the action of the muscular fibres of the stomach is altogether inverted, they contract from the pylorus, towards the cardia, and this anti-peristaltic motion, in which the contractions are effected with more force, more rapidly, and in a manner really convulsive, produces vomiting. Then, the action of the abdominal muscles is added to that of the stomach; the viscera are driven upwards and backwards, by the contraction of the large muscles of the abdomen; the diaphragm rises up towards the chest. If it sunk as it contracted, the œsophagus, which passes in the interval of its two crura, would be compressed, and the passage of the alimentary substances by the cardiac orifice, could not take place. Accordingly, it is observed, that it is only during expiation, that any thing passes from the stomach into the œsophagus. Vomiting may depend upon the obstruction of the pylorus, on the too irritating impression of any substance on the coats of the stomach; it may be produced by the irritation of some other organ with which the stomach is in sympathy, &c.

Digestion in the stomach is essentially assisted by nervous influence. Many physiologists, since Brunner, have found that the tying of the eighth pair of nerves (the pneumo-gastriques) provoked vomiting and retarded the work of digestion*. As it is impossible to make this experiment without affecting respiration, a function of very different importance, it becomes difficult to know, whether the derangement of digestion did not proceed from the general disturbance brought upon all the functions: however, the brain does appear to be in more immediate sympathy with the stomach, than with any other part of the digestive tube. Disgust from the recollection of loathed food excites vomiting. A more than ordinary exertion of the brain relaxes, diorders, and will even suspend, altogether, the functions of the stomach: an unexpected piece of news, a violent emotion, are attended with a cessation of the strongest sensation of hunger. It would be useless to bring together, in this place, proofs of the intimate connexion subsisting between the brain and the stomach, through the intervention of the pneumo-gastric nerves, for, the connexion is questioned by no one.

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* Dr. Haighton has proved, in the most satisfactory manner, that a ligature on the eighth pair of nerves, far from inducing vomiting, renders the stomach incapable of rejecting its contents, even though excited by the most powerful emetics. T.

See Memoirs of the London Medical Society, vol. II, page 512.

XXV. *Of digestion in the duodenum.* The food, on quitting the stomach, enters the duodenum and there experiences new changes, as essential as those which were produced upon it, by digestion in the stomach. It might even be said, that as the essence of digestion and its principal object is the separation of the food into two parts, the one recrementitious and the other chylous or nutritious, the duodenum in which that separation is performed, is its principal organ. In fact, however carefully one may examine the grayish chyme which is sent out of the stomach, it will be discovered to be a mere slimy homogeneous pulp; and, in more than a hundred animals which I have opened during the process of digestion, I never observed the absorbents of the stomach filled with real chyle, like those of the intestines.

The duodenum may be considered as a second stomach, very distinct from the other small intestines, by its situation exterior to the peritoneum, by its size and by its readiness of dilatation, the size and regularity of its curvatures, the great number of valvulæ conniventes with which its inner part is furnished, the prodigious quantity of chylous vessels which arise from it, and especially by its receiving, within its cavity, the biliary and pancreatic fluids. If the situation of the duodenum and the peculiarities of its structure are attended to, it will be readily observed, that every thing in that intestine, tends to slacken the course of the alimentary substance, and to prolong its stay within it, that it may remain the longer exposed to the action of these fluids.

The duodenum is, in fact, almost entirely uncovered by the peritoneum, a serous membrane, which like all those that line the inside of the great cavities, and reflect themselves over the viscera which they contain, by furnishing them external coverings, admits but of little extension and seems to stretch, when these viscera become dilated, only by the unfolding of its numerous duplicatures. Fixed by a rather loose cellular tissue to the posterior side of the abdomen, the duodenum is susceptible of such dilatation, as to equal the stomach in size, as is sometimes seen, in opening dead bodies. Its curvatures depend on the neighbouring organs, and seem almost invariably fixed; lastly, numerous valvulæ line its inner surface, so as to add to the friction, and to increase the extent of surface, and thereby the number of absorbents destined to take up the chyle separated in the duodenum, from the excrementitious part of the food, by the action of the fluids poured into it, from the united ducts of the liver and pancreas.

XXVI. *Of the bile and of the organs which serve for its secretion.* The bile is a viscous, bitter, and yellowish fluid, containing a great quantity of water, of albumen to which it owes its viscid condition, and oil to which the colouring and bitter principle is united. Soda, to which the bile owes the property of turning vegetable blues to a green colour, phosphates, carbonates, and muriates of soda, phosphates of lime, and of ammonia; and, lastly, as some say, oxide of iron, and a saccharine substance resembling the sugar of milk. This fluid, which the ancients looked upon as animal soap, fitted for effecting a more intimate mixture of the alimentary matter, by combining its watery with its fat and oily parts, is, therefore, extremely compound: it is at once watery, albuminous, oily, alkaline, and saline. The liver which secretes it, is a very bulky viscus, situated in the upper part of the abdomen and kept in its place, chiefly by its attachment to the diaphragm, of which it follows all the motion.

The hepatic artery, which the cœliac sends off to the liver, supplies it only with the blood requisite for its nutrition: the materials of its secretion are brought by the blood of the vena portæ.

This opinion on the uses of the hepatic artery, which I take up with Haller, cannot rest upon the experiments of those who pretend to have seen the secretion of the bile going on, after it was tied. Besides that the position of this vessel makes the operation almost impossible, which gives me reason to doubt if ever it was practised,—by intercepting the course of the arterial blood carried to the liver, this viscus, even under the received hypothesis, would remain deprived of nourishment and of action; and the vena portæ would supply it, in vain, with a blood on which it could exert no influence. When this vein is tied, which it is far more easily done than the artery, the secretion of bile is seen to stop: but the experiment which suspends the abdominal venous circulation, is too speedily fatal, to justify any conclusive inference. It is on analogical proofs, that the received hypothesis rests, touching the manner of the biliary secretion. The hepatic artery, remarkably lessened by the branches it has sent off in its way towards the liver, is to that organ what the bronchial arteries are to the lungs; and in the same manner, the branches of the vena portæ, spread through its substance, may be compared to the system of pulmonary vessels. It is still to be confessed, however, that the enormous bulk of the liver, its being found in almost all animals, and the quantity of blood carried into it by the vena portæ, compared to the small secretion there is of bile, lead to the belief that the blood sent to it from all the other organs of digestion, undergoes changes there, on which Science possesses, as yet, no certain data, though the chemists maintain, that the liver is, in some sort, the supplementary organ of the lungs, and assists in clearing the blood of its hydrogen and carbon.

This name of *vena portæ* is given to a particular venous system, enclosed in the abdominal cavity, and formed as follows: the veins which bring back the blood of the spleen, and the pancreas, of the stomach and intestinal canal, are united in a very large trunk, which ascends towards the concave face of the liver, and there divides into two branches. These lie in a deep fissure in the substance of this viscus; they send out, through all its thickness, a multitude of branches, which divide like arterial vessels, and end, in part, by opening into the biliary ducts or pores, and, in part, by producing the simple hepatic veins. These veins, situated chiefly towards the convex or upper surface of the liver, bring back, into the course of the circulation, the blood which has not been employed in the formation of bile, and that which has not served to nourish the substance of the liver: for, they arise equally from the extremities of the vena-portæ, and from the extremities of the ramifications of the hepatic artery.

The liver differs from all organs of secretion, in this, that the materials of the fluid it elaborates, are not supplied to it by its arteries. It should seem that the bile, a fat and oily fluid, in which hydrogen and carbon predominate, could be drawn only from venous blood, in which, as is known, these two principles are in superabundance. The blood acquires the venous qualities, as it passes along the circuitous course of the circulation, and is supplied with hydrogen and carbon the more fully, the slower it flows. Now, it is easy to see, that all is naturally disposed for slackening the circulation of the hepatic blood, and to give it, eminently, the distinguishing properties of venous blood. The arteries which furnish blood to the organs, in which the vena portæ rises, are either very flexuous as the splenic, or frequently anastomose, like the arteries of the intestinal tube, which of all that are in the body, abound most in visible divisions and anastomoses. It will be seen in the chapter on circulation, how well these dispositions are adapted for retarding the course of the arterial blood. Once carried into the organs of digestion, the blood stays there, whether it be that the coats of the hollow viscera being collapsed or closed upon themselves, hardly yield it passage, or that the organization of some one of these viscera is favourable to its stagnation.

The spleen seems to serve this purpose. Does this dingy and soft viscus, lodged in the left hypocondrium, and attached to the great fundus of the stomach, receive the blood into the minute cells of its spungy parenchyma, or does this fluid merely traverse, very slowly, the delicate and tortuous ramifications of the splenic vessels? In other respects, there is no organ that exhibits more variety of number, of bulk, of figure, of colour, and of consistence. Sometimes manifold, often divided into several lobes by deep clefts; its bulk varies, not only in different individuals, but even in the same, at different times of the day, as the stomach, full or empty, admits or rejects the arterial blood, and compresses the spleen between its large extremity, and the ribs under which it is situated, or leaves it free.

The blood which fills the tissue of the spleen, blacker, more fluid, richer in oily principles, owes all these qualities, which led the ancients to consider it as a peculiar subtance, called by them the atra bilis or black bile, to its long protracted continuance within that viscus. The branches, which by their union form the vena portæ, have thinner parietes than the other veins of the body, they are not furnished with valves, and they do not readily free themselves of the blood which fills them. The action of these veins is, in fact, so feeble, that it would not suffice to enable them to carry the blood onward, if the gentle and alternate compression of the diaphragm and abdominal muscles on the viscera of the abdomen, did not favour its circulation. On reaching the liver, the blood, which is highly venous, is further slackened in its circulation, by the increased dimensions of the space in which it is contained, the united caliber of the branches of the hepatic vena portæ, exceeding considerably that of the principal trunk. Besides, these vessels are enveloped in the parenchymatous substance of the liver, and can act but feebly. It, therefore, circulates slowly through that organ, and, with difficulty, returns into the course of circulation. The hepatic veins, which are of pretty considerable caliber, and without valves, remain constantly open, their parietes cannot close and contract on the blood which fills them, on account of their adhesion to the parenchymatous substance of the liver. They open into the vena cava, very near the place at which that vein terminates into the right auricle. The regurgitation of the blood, during the contraction of that cavity of the heart, is felt in the veins, and the blood forced back towards the liver, is exposed for a longer time to its action.

The spleen, therefore, performs only preparatory functions, and may be considered as the auxiliary of the liver, in the secretion of the bile. It is observed, that the quantity of the latter increases, after the spleen has been extirpated, and that it is less yellow, less bitter, and always imperfect. The blood which circulates in the omentum, is very similar to that of the spleen; I would even say, that it contains oily particles, if the drops which I have clearly noticed on its surface, might not have come from the adipose tissue of the omentum, which allows the fluid contained in its cells to flow, when a small puncture is made into it, in examining the blood contained in its veins.

The bile secreted in the tissue of the liver* is absorbed by the biliary ducts, the union of which forms the hepatic duct. The latter issues from the concave surface of the liver, and conveys the bile, either immediately into the duodenum, by means of the ductus communis choledochus, or into the gall bladder. This small membranous pouch, which adheres by means of cellular tissue to the lower surface of the liver, is in some animals entirely distinct from that organ, and connected to it, only by the insertion of its duct, into that which comes from the liver. Its inner membrane is soft, fungous, plicated, and always covered with the mucus, secreted by the glandular criptæ which it contains. This mucus defends the gall bladder against the action of the bile which it contains. The almost parallel course of the hepatic and cystic ducts, the acute angle at which they meet, renders it difficult to account for the passage of the bile into the gall bladder. It appears, that when the duodenum is empty, the bile regurgitates, in part, from the hepatic duct into the gall bladder, collects within it, becomes thicker and yellower, and acquires a greater degree of bitterness. Consequently, the use of the gall bladder, is to serve as a reservoir to a portion of the bile, which, by remaining within it, is improved in quality, acquires consistence and bitterness, and is heightened in colour, by the absorption of its fluid parts.

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* See, in the chapter on secretion, the laws which that function obeys.

XXVII. The irritation produced on the parietes of the duodenum, when distended by the chyme, is propagated to the gall bladder, by the cystic and common ducts. Its parietes then contract, and oblige the bile to flow, along this cystic duct into the ductus communis choledochus. The pressure of the distended intestines on the gall bladder, favours the excretion of bile. The hepatic bile is also more abundantly poured into the duodenum during digestion, from being secreted in greater quantity by the liver, which participates in the irritation affecting the organs of digestion, and secretes a greater quantity. The cystic and hepatic bile, mixed in the ductus communis choledochus, undergoes a change before entering the duodenum, by uniting with the fluid of the pancreas. The excretory duct of the pancreas, a glandular organ, which, in structure, bears so great an analogy to the parotid glands, that some physiologists, assuming an indentity of functions, have called it the abdominal salivary gland, joins the biliary duct, before the latter opens in the duodenum, after having insinuated itself obliquely between the coats of that intestine. It arises within the pancreas, from a great number of radicles which join it, like the feathers of a quill to a common trunk. Its caliber increases in size, as it approaches the large end of the pancreas, situated on the right, in the concavity of the second curvatnre of the duodenum. Nothing precise is known, with regard to the nature of the pancreatic fluid; the striking resemblance of the pancreas to the salivary glands leads to a presumption, that this fluid bears considerable analogy to the saliva. The quantity of fluid secreted by the pancreas is likewise unknown, but it must be considerable, if one may judge from the great number of nerves and vessels which pervade its glandular tissue, and its quantity is, most probably, increased by the irritation of the food in the duodenum.

This combination of the united pancreatic and biliary fluids poured on the chyme, penetrates it, renders it fluid, animalizes it, separates the chylous from the excrementitious part, and precipitates whatever is not nutritious. In bringing about this separation, the bile itself seems to be divided into two parts, its oily, coloured, and bitter portion passes along with the excrements, sheathes them, and imparts to them the stimulating qualities necessary to excite the action of the digestive tube. Its albuminous and saline particles combine with the chyle, become incorporated to it, are absorbed along with it, and return into the circulation. There may, in fact, be noticed in the alimentary mass, after it has undergone this combination, two very distinct parts, the one is a whitish milky substance, which swims to the surface and is the least in quantity; the other is a yellowish pulp, in which, when digestion is healthy, it is not easy to recognize the nature of the food. When the liver is obstructed, and the bile does not flow in sufficient quantity, the fæces are dry and discoloured; the patients are troubled with obstinate costiveness, the excrement, uncombined with the bitter and colouring matter of the bile, not proving sufficiently irritating to the intestinal canal.

We have just mentioned how the separation of the chyle is performed; but the mechanism of that separation and the process of chylification are absolutely unknown. How does the union of the bile to the chyme operate, in extracting from the latter the recrementitious part, and in making it swim above the rest? Is there any connexion between that process and the nature of the constituent principles of the bile? the knowledge of the composition of the bile, affords as little assistance in the explanation, as does the knowledge of the chemical properties of the semen, in understanding the admirable function of generation. All these acts of the animal economy, are as mysterious and inexplicable, as the action of the brain in producing thought, a phenomenon which so many physiologists have considered as exceeding the power of matter, and for which they seem to have reserved all their admiration, though *nil mirari*, which I would translate by *wondering at nothing*, ought to be the motto of any one who has made some progress in the study of the laws of life.

XXVIII. *Of the action of the small intestines.* After remaining a certain time within the duodenum, the alimentary mass decomposed by the bile, or rather by the pancreatico-biliary fluid, separated into two parts, the one chylous, the other excrementitious, passes into the jejunum and ileum, which are not easily distinguished from each other, and which differ in their relative length, according to the elements on which anatomists ground the distinction.*

The jejunum and the ileum alone occupy nearly three-fourths of the whole length of the digestive canal; they are straiter than the duodenum, and do not dilate so readily, because the peritoneum, which forms their outer covering, lies over their whole surface, with the exception of the posterior border at which their vessels and nerves enter. It is along that border, that they are fixed to the mesentery, a membranous band formed by a duplicature of the peritoneum, which contains the vessels and nerves going to the jejunum and ileum, which prevents knots from forming in the intestines, and is a security against the occurrence of intus-susceptio. It is well-known, however, that in some rare cases, intus-susceptio does take place, with utmost danger of the patient's life, who generally dies in the agonies of insufferable cholic pains, which nothing can alleviate. The progress of the food, along the small intestines, is retarded by its numerous curvatures, very aptly compared by some physiologists to the windings of a meandering stream which fertilizes the soil it waters. These numerous convolutions of the intestinal canal favour the long continued presence of the food within its cavity, so that the chyle expressed from the excrementitious part by the peristaltic contractions of the intestine, may present itself to the inhaling mouths of the lacteals, by which it is to be absorbed. These chylous absorbents are in greatest number on the surface of the valvulæ conniventes, which are circular folds of the inner membrane, and these are at a greater distance from each other, the nearer they are to the termination of the ileum. The valvulæ conniventes not only slacken the progress of the food, but by their projections, they sink during the contraction of the bowels, into the alimentary mass, and the lacteals on their surface take up, from its inmost part, the chyle which they are destined to absorb.

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* The redness of the parietes of the jejunum, the empty condition of that intestine, its situation in the umbilical region, the great number of its valvulæ conniventes, do not distinguish it from the ileum, for, the colour of the intestinal canal varies in different parts of its extent, and the substances which fill it are found in different parts of the canal, according to the progress of digestion at the time the parts are examined; according as the convolutions are situated within the cavity of the pelvis, or rise towards the epigastric region; according to the full or empty state of the bladder and stomach; and the number of circular folds, called valvulæ conniventes, diminishes, as one gets near to the termination of the ileum. Winslow got over the difficulty, by considering the upper two-fifths of the small intestines as jejunum, and the remaining three-fifths as ileum. This last division, from measurement, is wholly arbitrary, and is besides useless, for, there is not, perhaps, above one occasion in which it would be interesting to distinguish the jejunum from the ileum. In operating for hernia, when the intestine is mortified, one would decide the more readily to leave an artificial anus, if one could be sure that the gangrenous portion belonged to the latter intestine; but of this it is absolutely impossible to be certain.

The number of the valvulæ conniventes diminishes with that of the lymphatics. The progress of the alimentary substance is gradually accelerated, as it parts with its nutritive and recrementitious particles. A quantity of mucus, secreted by the internal membrane of the small intestines, envelops the chymous mass and promotes its progress, by lubricating it; this intestinal mucus thrown out by the exhalant arteries imbues it, renders it liquid and adds to its bulk.—This fluid which seems to partake of the nature of albumen and gelatine, and to hold several saline substances in solution, is, for the greater part, recrementitious, and must be very considerable in quantity, if we may judge from the caliber of the mesenteric arteries, and from the extent of the internal surface of the intestines. It, is, however, scarcely possible, that this exhalation should amount to eight pounds in twenty-four hours, according to Haller's calculation, who, as we shall observe, when we treat of the secretions, has generally over-rated their amount.

The peristaltic contractions, by the assistance of which, the alimentary mass is sent along the whole course of the small intestines, do not occur in a regular and uninterrupted succession, from the stomach to the cœcum. This undulatory and vermicular motion manifests itself at once, in several points of the length of the tube, whose curvatures straighten themselves at intervals. In this action, the intestinal curves are decomposed into a great number of short straight lines which meet, so as to form obtuse angles. The peristaltic motion which affects the muscular fibres of the intestines, is caused by the irritation of the alimentary substance on the sentient parietes of the canal along which it descends, towards the great intestines. The jejunum and the ileum, covered by the peritoneum, except at the part which connects them to the mesentery, at the time of dilatation, separate the two peritoneal laminæ, forming the mesentery. They occupy the space between the branches of the mesenteric vessels, whose last division is always at some distance from the adhering edge of the intestine. If this division of the vessels had taken place, nearer to the union of the intestine and mesentery, the intestinal canal would not have admitted of dilatation, without stretching the vessels situated at the angle of separation. It is likewise observed, that in the portions of the digestive tube which are most susceptible of dilatation, the last vascular divisions are most distant. Hence the left gastro-epiploic artery is always at a greater distance from the great curvature of the stomach, than the right, a circumstance of which no anatomist has hitherto taken notice.

XXIX. *Of digestion in the great intestines.* The alimentary mass, after it has parted with nearly the whole of its nutritive particles, passes from the ileum into the cœcum; it then is received into the great intestines, which are more spacious, though shorter, than the small, forming scarcely a fifth of the whole length of the digestive tube.

A musculo-membranous valvular ring is placed at the oblique insertion of the ileum into the first of the great intestines. This valve, called after Eustachius or Bauhinus, who are considered as its discoverers, though the merit of the discovery belongs to Fallopius, is formed of two semi-circular segments, the right edge of which is free and floats towards the cavity of the cœcum. The more the parietes of that intestine are distended by the substances which it contains, the greater is the difficulty to the retrograde flow of such substances, for under those circumstances, the two extremities of the valve are at a distance from each other, and its edges, which are free, close on each other, like those of a button hole whose angles are drawn in opposite directions; besides, the muscular fibres which enter into its structure, render it capable of exerting constriction. It is, therefore, calculated to permit the ready flow of matter, from the ileum into the cœcum, and forcibly prevent their return into the small intestines. There are facts which lead to a belief, that its resistance is sometimes overcome, and that a clyster, thrown in with violence, would force the valve and be thrown up by vomiting. The great intestines may be considered as a kind of reservoir destined to contain, for a certain time, the excrementitious residue of our solid aliments, so as to save us the disgusting inconvenience of constantly parting with it.

As the peritoneum does not wholly cover the great intestines, they are capable of considerable dilatation, and of extending into the cellular substance which connects them to the posterior part of the abdomen. Their muscular coat which, in a manner, is the base of the intestinal tube, does not consist throughout, of circular and longitudinal fibres. The latter, collected into fasciculi, form three narrow bands, in the intervals of which, the parietes of the gut are exceedingly weakened, and consequently capable of greater extention. These longitudinal fibres being, besides, shorter than the intestine, crease it transversely, and form within it a number of cavities and cells, marked outwardly by prominences separated by depressions. If, in addition to these peculiarities of structure, it be considered, that in the cœcum and a great part of the colon, the contents of the bowels have to ascend against their own weight; that the curvature forming the sigmoid flexure of the colon is very considerable, and that, in short, the rectum before its outer termination in a narrow aperture, is considerably dilated, it will be evident, that in the great intestines, every thing tends to protract the stay of the excrements.

The appendicula vermi-formis of the cœcum is, in man, too small to perform this office; in the herbivorous quadrupeds, in which it is much larger, and sometimes not single, it may serve as a reservoir to the fæcal matter. Its existence merely shews in man, an analogy to those animals in which it is truly useful, and it concurs in manifesting, that Nature, in the formation of particular organs, in certain kinds of animals, aims at a mere outline which she fills up in others, to shew, as it were, that there are points of resemblance between all beings whom she has gifted with life and motion.

While in the great intestines, the alimentary substance becomes merely fæcal, by parting with the small quantity of chyle which it may yet contain. The number of the absorbents decreases progressively from the cœcum to the rectum; the small number of these vessels, accounts for the difficulty of throwing in nourishment by means of clysters, when there is an obstruction to deglutition. The excrements thicken, harden, and become formed or moulded, in the cells of the colon, they are then urged by the peristaltic action, into the rectum, in the cavity of which they accumulate, till they excite on its parietes an action which determines their expulsion.

XXX. *Of the evacuation of the fæces.* When a call to evacuate the fæces is experienced, the rectum contracts, while the diaphragm descending, and the abdominal muscles receding towards the spine*, thrust the viscera of the abdomen towards the cavity of the pelvis, and compress the intestines which are filled with fæcal matter. During these efforts, the perineum perceptibly descends, and the fibres of the levator ani are somewhat elongated. The combined action of the rectum and of the abdominal muscles, overcomes the resistance of the sphincters, and the alvine evacuation takes place, and is facilitated by the secretion of the mucous follicles of the rectum: these glands, squeezed by the pressure of the fæces, pour out their contents and lubricate the circumference of its lower aperture. When the fæces have been voided, the diaphragm rises, the large muscles of the abdomen cease to press backwards and downwards upon the viscera of that cavity; the perineum ascends and the sphincters close, till a renewal of the same call, again brings on the same action.

The call to void the fæces, is more frequent in children than in adults, because, at an early period of life, the sensibility of the intestinal canal is greater, the contents of the bowels, more fluid, and digestion more active. As we advance in years, sensibility becoming impaired, and contractility experiencing a proportionate loss of power; the secretions being, likewise, less abundant, the bowels become sluggish, the stools more scanty and indurated. They are, likewise, less frequent and copious in women than in men, whether it be, that the digestive power extracts from the aliment, a greater proportion of nutritious matter, or that the menstrual evacuation being a kind of substitute for the intestinal secretions, less remains to add to the bulk of the excrementitious mass. The evacuation of the fæces, may be brought on by throwing liquids into the rectum, which dilute the fæces, detach them from the parietes of the intestines, and, exciting on these parietes an irritation to which they are not accustomed, determine their contraction.

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* Some physiologists have considered as unnecessary, this concurrent action of the diaphragm and abdominal muscles; they ground their opinion on the circumstance, that animals whose abdomen has been laid open are capable of voiding their fæces. Astruc, one of the luminaries of Montpellier, denies the action of the abdominal muscles, in the efforts which one makes at stool, and in support of his opinion, he brings forward this geometrical proposition "that a cord disposed in the form of a circle, can, by contracting, shorten itself in an infinitely small degree, and, therefore, not perceptibly." On which Pitcairn, humorously enough observes, that Astruc had never practised what he reasons upon: "*credo Astruccium nunquam cacasse.*"

The fetor of the excrements depends on their incipient putrefaction in the great intestines. This decomposition is, almost always, attended with the extrication of gases, in which sulphureted hydrogen prevails. This gas, which at times escapes, and which at others impregnates the fæces, is the cause of the black colour which they give to silver exposed to their action. One may recognize in the excrements, the colouring matter of vegetables, such as the green colour of spinage, the red of beet root; one may, likewise, find among them, the fibrous parts of plants and animals, the indurated bark, and the seeds covered with their husks. The digestive juices have so little action on husks, that seeds which have not been broken down by the organs of mastication, frequently continue capable of vegetation.

During the progress of digestion, the food contained in the stomach and intestines absorbs or extricates different gases. M. Jurine, of Geneva, opened the body of a maniac who had been dead a few hours, and collected the gases which escaped; he observed, that the proportion of oxygen and carbonic acid diminishes from the stomach towards the great intestines, while, on the contrary, there is, in these, an increased proportion of azote; that hydrogen is more abundant in the great than in the small intestines, that it is less in quantity in these than in the stomach. Do the oxygen and azote form a part of the atmospherical air which is taken in with the food and with the saliva, and which is disengaged by the heat of the intestinal canal? Or are these gases the result of the decomposition of the food and of the intestinal fluids? Besides, may not the gas contained in the intestines of a dead body, have been formed at the moment of death? We know that, in several instances, at the moment contractility is forsaking our organs, the intestines become distended by gas which hastens the approach of death, by impeding the descent of the diaphragm.

Digestion, when healthy, is unaccompanied by the production of gases. In indigestion, there almost always escapes carbonated or sulphureted hydrogen gas, which produces the offensive smell of the air which escapes at the anus; this smell is different from that of the flatus which are brought upwards, these contain pure hydrogen or carbonic acid gas. The latter is, likewise, sometimes voided by the rectum, but less frequently than hydrogen combined with carbon, sulphur, or even phosphorus. Is not ammonia itself extricated, and does it not accompany the evacuation of the fæces in certain putrid diarrhœas, as in dysentery combined with low fever? Though the formation of this gas implies a putrefactive motion opposed to the vital principle, may not this decomposition commence in substances lying in the great intestines, when these are become almost inert from the impaired condition of the vital power. This would not be the only instance of a chemical process taking place in the intestinal canal, notwithstanding the counteracting influence of vitality. Thus, on some occasions, grapes eaten in too great quantity, ferment and produce carbonic acid gas, in such abundance, that this elastic fluid overcomes the resistance of the intestines. This is the kind of distention from flatulence which is cured by drinking plentifully of cold water, which dissolves the gas naturally soluble in that fluid.

XXXI. *Of the secretion and excretion of the urine.* The fluids absorbed with the chyle, and taken up by the lymphatics of the intestinal tube, dilute the nutritive part extracted from the solid aliment, and serve it as a vehicle. When they have reached the mass of the blood, they increase its quantity, diminish its viscidity and render it more fluid; going along with it throughout the whole course of the circulation, they supply moisture to all the parts of the body, and become loaded with the molecules detached from them by the vital motion. Then, conveyed to the urinary organs, they become disengaged from the rest of the fluids, carrying along with them a number of products of every kind, which by a longer stay in the animal economy, would not fail to occasion a manifest disturbance in the exercise of the functions.

XXXII. The rapidity with which we void, with the urine, certain diuretics, has induced several physiologists to think, that there exists a direct communication between the stomach and bladder; no one, however, has ever succeeded in pointing out those peculiar ducts, which might serve to convey the urine from the stomach to the urinary organs, without taking the circuitous course of absorption and of the circulation, and, besides, the learned Haller has proved, by accurate calculations, that the size of the renal arteries, whose caliber amounts to an eighth of that of the aorta, and the quickness with which the blood flows, sufficed to account for the shortness of the time in which certain fluids reach the urinary organs.

A thousand ounces of blood pass through the renal tissue in the space of an hour: supposing that this fluid contains only a tenth of the materials fit for supplying urine, a hundred ounces, or seven pounds and a quarter, may be given out in this short time: and never, with the most copious and diuretic drinks, does more of it pass in an hour. We shall see, however, in treating of absorption, that it is not absolutely impossible, that by means of the numerous anastomoses of the lymphatics, this set of vessels may carry a liquid, directly from the stomach into the bladder. It would be superfluous to mention, in this place, the varieties observable in the kidneys, in point of number, size, and situation. These two lobular viscera, composed of the union of from twelve to fifteen glandular bodies, divided in the fœtus, and in some quadrupeds, attached to the posterior part of the abdomen, behind the peritoneum, are surrounded with a cellular covering of different thickness, and particularly remarkable by the consistence, approaching to that of tallow, of the fat which fills its cells.

If ever the art of man shall penetrate into the mystery of the intimate structure of our organs, it seems probable that the kidneys will furnish the first solution of the problem. Even coarse injections pass readily from the renal arteries into the ureters, or excretory ducts of the kidneys; a convincing proof of immediate communication among the minute arteries, which, exceedingly tortuous, form, with the minute veins, the cortical or outward substance of the kidneys, and the straight urinary tubes, which, distributed in conical fasciculi, in the interior of these organs, constitute what has been called its tubuli and papillæ. The passage of injections from the arteries into the renal veins, is as easy; and I have often seen the coarsest liquids flowing at once by the ureters and by the emulgent veins. This free communication between the arteries, the veins, and excretory ducts of the kidneys, gives an idea of the rapidity with which the blood must flow through these organs, whose firm consistence allows a very moderate dilatation to the vessels; and suggests the possibility of a sort of filtration of the urinary fluid, the secretion of which would be only a succession of chemical or mechanical separations, from the blood, in its passage along very minute ducts, of a bore progressively decreasing. This was the opinion, at least, of Ruysch, whose system on the intimate composition of our organs, and on the immediate continuation of the blood-vessels with the excretory ducts, is chiefly founded on the facts of structure, discovered to him by his beautiful injections of the renal arteries.

The kidneys are of duller sensibility, and less energetic action than the other glands. The force of life has less to do in their secretion, and their functions may be more readily explained on the principles of chemistry or hydraulics.

XXXIII. If we attempt, indeed, to apply to the urinary organs the fundamental laws on the mechanism of secretions*, it is soon seen, that these organs are not under their absolute controul. Of all the animal fluids, urine is the one most complex in its elements, and most variable in its qualities. Not only do foreign substances sometimes appear in it, affect, and even change its composition; other fluids may, at times, mix with it, and disguise it altogether. Thus credible observers tell us of the appearance in urine, of bile, fat, milk, blood, pus, of which many facts may be found collected in Haller's great work on physiology. The kidneys, then, have less sensibility than the other secretory organs: they reason less, if I may venture on the expression, on the sensation produced by the various substances in the blood: their action is also less powerful; it does not so intimately affect the fluid subjected to it. It does not change the heterogeneous qualities of those that are mixed with it, and allows them to pass in a pure state.

This multitude of elements in the composition of urine, had surely been understood by the ancients, before it was demonstrated by modern chemistry; for, they considered it as a sort of extract of animal sbstance, as a real lixivium, carrying off all that is impure in the economy, and gave it the name of *lotium*, which indicates that destination.

Finally, the secretion of urine is more uniformly carried on: it is continual, or at least, does not exhibit so prominently those alterations of action and repose, so apparent in the work of the other secretory organs. When, in a case of retention of urine, we introduce a catheter into the urinary bladder, and leave it there, the urine keeps dropping continually, and would wet the patient's bed, if the orifice of the catheter were not kept closed. In the memoirs of the Academy of Sciences for the year 1761, there is related a case of singular conformation of the urinary bladder. This musculo-membranous viscus protruded through an opening at the lower part of the linea alba, and was turned inside out, so as to present, externally, its mucous membrane. This case afforded an opportunity of observing the continual flow of the urine through the orifices of the ureters, and of ascertaining the different circumstances attending this process, either with regard to the qualities of this fluid, or to the quantity which might be voided, in a certain space of time, and in this respect, there was a good deal of difference, according to the state of sleep and waking, to the quantity and to the diuretic qualities of the drink.

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* See the Chapter on *Secretion*.

The urine contained in the ureters is turbid and imperfect; its constituent parts are not thoroughly blended together, as may be observed, if made to flow, by compressing the kidneys in a dead body. It improves by passing along those ducts, acquires the characteristic qualities of urine, oozes at the surface of the papillæ, and flows into the membranous calices which embrace the rounded terminations of the tubuli uriniferi. The union of the calices forms the pelvis, or the expanded portion of the ureters, or membranous ducts, along which the urine is incessantly flowing into the bladder. The urine flows into the bladder by its own weight, and especially by the action of the parietes of the ureters, which possess a certain degree of contractility. To the above causes, may be added the concussions excited by the pulsations of the renal arteries, behind which the pelvis of the kidney is situated, and by the pulsations of the iliac arteries, in front of which the ureter passes, before enteringthe cavity of the pelvis; the alternate compression from the viscera of the abdomen, during the motions of respiration; the concussion attending bodily exercise, as riding on horseback, walking, running, &c.; the pressure of the column of urine from the kidneys, and the want of resistance towards the bladder.

XXXIV. The urine is continually passing, in drops, into the bladder, it separates its parietes, without, however, exciting in them any perceptible impression, as they are accustomed to its stimulus. The urine cannot accumulate in the musculo-membranous cavity of the bladder*, which is situated, exterior to the peritoneum, in the cavity of the pelvis, behind the pubis, above which, in the adult, it never rises, except when excessively distended, unless it is prevented from flowing along the urethra, or from returning by the ureters. This retrograde flow is prevented by the oblique insertion of these ducts, which pass, for some distance, between the muscular and mucous coats of the bladder, before opening within it, towards the posterior angles of the trigone vesical*, by openings of smaller dimensions than their cavity. The inner coat of the bladder, raised over these apertures, gives them the appearance of being provided with valves, which fit the better these orifices, according as the urine contained in the bladder, by separating its parietes, presses against each other the coats by which they are formed, and between which the ureters pass, along a space of from seven to eight lines.

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* In the numerous tribe of birds, the bladder is wanting. In them, the ureters open into the cloaca, a musculo-membranous bag, which supplies the place of the rectum, bladder, and uterus, and which serves as a reservoir to the solid excrements, to the urine and to the eggs detached from the ovaria. The urine of birds dilutes the fæces and furnishes the carbonate of lime which forms

The urine which flows into the bladder, requires a certain degree of force, to separate its parietes on which the weight of the intestines presses. This is effected by no other power, than by that which causes the flow of the urine along the ureters, and though inconsiderable, it will appear sufficient, if it be considered that the fluids which pass from a strait channel into a larger cavity, act on every superficial portion of its parietes equal to the area of the channel, with a power equal to that which determines their flow into the latter; so that if the urine descends along the ureters, with a degree of force equal to one, and if the inner surface of the bladder is a thousand times more extensive than the area of the ureters, the power will be multiplied a thousand fold.

This purely mathematical proposition is expressed by saying, that the force with which the urine passes along the ureters, is to that by which the parietes of the bladder are distended, as the caliber of the ureters is to the superficies of the bladder.

The pressure which the urine, accumulated within the bladder,

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the basis of the egg shell. It has such a tendency to concretion, that I have always observed, in dissecting various fowls of different kinds, an earthy, saline or crystallized substance, forming white striæ easily seen in the fluid of the ureters, through their thin and transparent coats. Hence one may readily conceive, how frequently calculi would form in these animals, if their urine accumulated and remained, for any length of time, stationary in a cavity destined to contain it.

* The French anatomists give the name of *trigone vesical*, to that portion of the bladder included between the openings of the ureters and the neck of the bladder, and forming a triangle, whose base is represented by a line drawn from the opening of one ureter to the other, and whose apex is situated at the insertion of the urethra into the neck of the bladder. T.

exerts on the lower part of the ureters, does not prevent the force which determines its descent along the ureters, from carrying it into the bladder:—for, the column which descends along the ureters, being higher than that contained in the bladder, these two organs represent an inverted syphon, the longer branch of which is represented by the ureter.

The following are the causes which enable the bladder to retain the urine: the contraction of its sphincter, a muscular ring surrounding the termination of the urethra into the bladder: the angle formed by that canal, after it leaves the bladder: and lastly, the action of the anterior fibres of the levator ani, which surround the neck of that organ, surrounded besides and supported by the prostate gland. These fibres, which are calculated to compress the prostate over the neck of the bladder, and to raise the latter against the pubis, have been called by Morgagni, *pseudo sphincteres vesicæ.*

The urine, deposited by drops into the bladder, gradually separates its parietes. This musculo-membranous organ rises, and at the same time, carries upwards the convolutions of the ileum, and the peritoneum before which it lies, behind the pubis and the recti muscles with which it is in immediate contact. These relations of the peritoneum to the distended bladder, account for the possibility of puncturing it above the pubis, so as to let out an accumulation of urine, without penetrating into the cavity of the peritoneum. The urine remains a certain time in the bladder, according to the capacity of the latter, to the irritability and extensibility of its parietes, and according to the acrid or stimulating qualities of the fluid itself. Thus in old men, in whom the bladder has but a small degree of irritability and contractility, the urine is voided less frequently; it accumulates in greater quantity, and is, at times, evacuated with difficulty. The use of diuretics, especially of cantharides, renders the urine more stimulating, it excites powerfully the parietes of the bladder and incessantly stimulates it to contraction. Every cause of irritation seated within the bladder itself, or in its vicinity, renders more frequent the calls to void urine. This is observed in cases of stone in the bladder, of piles, gonorrhæa, &c. The urine, while in the bladder, becomes thicker from the absorption of its more fluid parts, its elements become more intimately blended, sometimes even, it appears to undergo a certain degree of decomposition.

XXXV. When, either by the extension which the urine occasions in the muscular fibres of the bladder, or by the irritation which it excites in the nerves distributed on its inner membrane, we experience in the pelvis a sensation of weight, together with a kind of tenesmus, which, as it extends along the urethra, warns us to void urine; then we bring on a contraction of the bladder, and joining to its action, that of the abdominal muscles and of the diaphragm, we expel the urine by a process very similar to that of the excretion of the fæces (XXIX). It should be observed, however, that in a healthy state of the parts, this assistance is required, only to overcome the equilibrium between the contractions of the bladder, and the resistance which the cause of retention opposes to the evacuation of the urine. After the simultaneous contraction of the diaphragm and abdominal muscles, to press down the intestines on the bladder, and to determine the first flow of the urine, we cease that effort, and the bladder alone, still supported by the weight of the surrounding viscera, which compress it as it empties itself, completes the evacuation. We repeat the first effort, only in case we wish to accelerate the flow of the urine. In the evacuation of the fæces, on the contrary, the muscular coat of the rectum requires the incessant co-operation of the respiratory powers, as these solid substances are evacuated with more effort than the urine. To prove, beyond a doubt, that the urine is evacuated, chiefly by the action of the bladder, one need but observe the violent, but useless straining of patients affected with retention of urine, from paralysis of the bladder*.

The urine is projected along the urethra with the greater force, as it passes from a spacious cavity, into a strait canal, and it is expelled with a force proportioned to that of the muscular coat of the bladder; we know, that in old men, this is so weak, that the jet of urine is not projected more than a few inches beyond the urethra. The urethra is not to be considered as inert in the evacuation of the urine, it closes upon it and accelerates its flow, aided in that action, by the bulbo-cavernous muscles to which several anatomists have given a name taken from their functions. *(acceleratores urinæ).*

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* It is scarcely credible that some physiologists should have considered this organ as inert and absolutely passive, in the evacuation of the urine, which, in their opinion, is performed, by the immediate pressure of the abdominal muscles and diaphragm on that cavity. Amid this variety of opinions, if you wish to come at the truth, you must take a medium. *Iliacos intrà muros peccatur, et extrà.*

The action of these muscles expels the last drops of urine which remain within the urethra, when the bladder is completely emptied. The contractile and tonic action of the urethra is so distinctly marked, that its spasmodic contraction may be enumerated, among the causes which frequently occasion a difficulty in introducing the catheter. If we attempt to inject fluids along the urethra, the moment we remove the pipe of the syringe which closes its external orifice, that instant, the parietes of the canal contract on the fluid and expel it with a rapid jet.

The bladder and the canal of the urethra are lined internally with a membrane, whose mucous follicles secrete a viscid humour calculated to protect the parietes of these organs, against the action of the urine, and to facilitate the evacuation of that fluid. This membrane, whose surface is more extensive than the cavities which it lines, forms a great number of folds, which disappear when the bladder is distended with urine. This mucus is secreted, in an unusual quantity, in catarrhal affections of the bladder, and becomes, likewise, more ropy and more albuminous. The mucous secretion of the glands of the urethra is altered in its quality, and becomes more abundant, from the action of the venereal poison, and gives rise to the discharge of gonorrhæa; the orifices of these lacunæ may stop the end of a catheter, so as to add to the difficulty of introducing that instrument*.

The urine cannot be voided at the same time as the fæces, when these, by their hardness, compress the prostatic and the membranous part of the urethra, situated before the lower extremity of the rectum. It is difficult, and often impossible, to void urine, during a violent erection, as the parietes of the canal are then closely applied to each other, by the turgescence of the corpus spongiosum and of the corpora cavernosa of the penis. The mode of sensibility of the urethra, is besides changed in such a manner, that it is calculated to permit only the emission of the seminal fluid.

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* When this operation is performed in a case of simple paralysis of the bladder, it is better to employ a very large catheter, which may stretch the parietes of the urethra and prevent their forming into wrinkles, and whose rounded beak may not get engaged in the lacunæ of that canal.

When in a case of retention of urine, the bladder rises above the pubis, its *bas fond* is carried upwards, and there is a period of excessive distention, at which, like the uterus in an advanced stage of pregnancy, it seems to make an effort to rise above the brim of the pelvis; under such circumstances in women, it is impossible to introduce the catheter, except by increasing the curve of the instrument.

When the bladder is completely emptied, it sinks behind the pubis; the tumour which it formed above these bones, while in a state of distention, collapses, the abdomen becomes less prominent, respiration more free, and there is a general feeling of lightness. The bladder cannot be completely evacuated, unless the pelvis is gently inclined forward; its *bas fond*, which is on a lower level than its neck, would, in any other posture, retain a certain quantity of urine.

XXXVI. *Of the physical properties of urine.* As this fluid varies in quantity in a healthy man, according to the quantity and diuretic qualities of the drink, the state of sleep or waking, the condition of the secretions, and especially of the perspiration, it is very difficult to determine, accurately, its proportions. Nothing varies more than its quantity, as may be ascertained, by comparing the different calculations on that subject, of a great number of physiologists. At times, the urine is less in quantity than the drink that has been taken in, at others, more. It may be affirmed, however, that the quantity of urine voided in twenty-four hours, is equal to that of the insensible perspiration in the same time, and it may, therefore, be estimated at between three and four pounds, in a healthy adult. Its colour varies, from a light lemon yellow, to an orange, approaching to red. Its smell and flavour are peculiar, and distinguish it from every other animal fluid. Its colour is, in general, darker, its smell and flavour stronger and more pungent, as it is less in quantity, as the circulatory system is more active and powerful, and as the substances of our food are more animalized. We all know how fetid and how scanty is the urine of carnivorous animals; how offensive to the smell is that of the cat! The specific gravity of urine is greater than that of distilled water, and varies, according to the quantity of saline and other substances, which it holds in solution; it is, likewise, slightly viscid, but not ropy like the serum of the blood, the bile, the saliva, and other albuminous fluids.

XXXVII. *Of the chemical properties of urine.* The peculiar qualities of urine are always more marked in a powerful and adult male, than in children, women, and weakly persons. By chemical analysis, the urine is found to contain eleven substances, dissolved in a considerable quantity of water, viz. urea, a gelatinous animal matter, muriates and phosphates of soda and ammonia, in separate or in triple salts, phosphate of lime, phosphate of magnesia, phosphoric, uric, and benzoic acids. Besides these substances which are constantly found in human urine, this fluid may contain a great number of others; and if it be true that the urinary system is to be considered as the emunctory of the whole economy, one would expect to find in it, in certain proportions and under different circumstances, the whole of the constituent principles which analysis has hitherto discovered in our solids and liquids. Hence, doubtless, the difference in the results obtained by the chemists who have investigated the nature of the urine, by allowing it to run into decomposition, or by applying to it various re-agents.

As the urine is, of all our fluids, that which has the greatest tendency to putrefaction, it should be examined shortly after being voided; it is then distinctly acid, but in a very short time, and especially if the heat of the atmosphere promotes and accelerates these changes, it becomes turbid, its component parts separate and form various precipitates. Urea and gelatine, which alone of its constituent principles are capable of fermentation and decomposition, give out ammonia, acetous and carbonic acids, and from thechemical attraction between these newly formed substances, and from the primitive elements, there are produced new compounds the knowledge of which is of the department of chemistry.

Of all the constituent parts of urine, the most essential is a substance of the consistence of syrup, deliquescent, susceptible of crystallization, to which M. Fourcroy has given the name of *urea*. This substance to which the urine owes its characteristic properties, its peculiar colour, smell, and flavour, which was imperfectly known to several chemists who had sketched some of its features, giving it different names, according to the notions they entertained of its nature, was never well understood till the late investigations of this celebrated professor*. It is a compound in which azote prevails, as is shewn by the immense quantity of carbonate of ammonia, which it gives out in distillation; it may be considered as the most animalized product, having such a tendency to the putrid fermentation, that, even while in the animal economy, it is liable to that decomposition, and might overcome the antiseptic influence of the vital power, if nature did not get rid of it by the evacuation of the urine.

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* See his work entitled: *Systême des connoissances chimiques*. 8vo, tom. X. page 153.

Sufficient attention has not hitherto been paid to the symptoms of urinary fever, an affection occasioned by the protracted retention of the urine within the bladder. I have observed, on several occasions, that no kind of fever is attended with more marked signs of what physicians term putridity. The urinous and ammoniacal smell exhaled from the body of the patients, the yellowish and oily moisture of their skin, the parching thirst with which they are tormented, the dryness and redness of their tongue and throat, their frequent and irritable pulse, combined with a flaccid and doughy feel of the cellular tissue, every thing indicates that the animal frame is threatened with the most speedy and dangerous decomposition.

I observed similar appearances in a cat and in a rabbit, in which I tied the ureters. Nothing is easier than to find the ureters and to perform this experiment. After a crucial incision of the parietes of the abdomen, on the left side, the intestines are pushed aside to the left, so as to apply a ligature on the right ureter, they are then pushed to the right, while the left ureter is tied. Both ureters are seen through the peritoneum, situated behind that membrane, in the lumbar region. When the ligatures have been applied to the ureters about their middle, the divided edges of the abdomen are brought together and united by sutures, and the body of the animal is wrapped round with a cloth soaked in some emollient decoction. At the end of six and thirty hours, the animals became exceedingly thirsty and restless, their eyes glistening; their saliva, which flowed copiously, exhaled a smell evidently urinous; on the third day, the cat was seized with vomiting of a slimy substance, remarkable by its having the same smell. This convulsive agitation was followed by an excessive prostration of strength; it died on the fifth day; the intestines were not inflamed, the bladder quite empty, the ureters distended with urine between the ligatures and the kidneys, and as large as the ring finger. The kidneys themselves, gorged with urine, were turgid, softened, and as if macerated. All the organs, all the fluids, the blood itself, partook of this urinous diathesis; putrefaction came on immediately after death, and at the end of a few days, an almost compleat decomposition of the body had taken place. In the rabbit the symptoms were less violent and rapid; it did not die till the seventh day; the smell of its whole body, though evidently urinous, was less offensive, and the putrefaction which succeeded was less rapid.

These two experiments confirm, in the first instance, what some authors have said of the absence of urine in the bladder, when the ureters have been tied, an undeniable proof that these are the only channels which convey the urine into the bladder, they likewise concur in affording the most convincing proof, that the kidneys are the emunctories by means of which the blood clears itself of that part of it which is animalized in excess: finally, they prove, that the retention of this fluid is the more dangerous to the animal economy, as the urine is itself more animalized.

Has nature the means of supplying the evacuation of urine by other excretions? might this highly recrementitious fluid be, without danger, evacuated by other emunctories? With a view to answer this interesting question, the kidneys have been extirpated in dogs. The removal of one kidney, did not prevent the secrétion from being carried on; in every case in which both kidneys were removed at once, the animal died in a few days, and on opening the body, there was uniformly found, a considerable quantity of bile in the gall bladder, in the small intestines, and even in the stomach, as if the urea had endeavoured to make its escape in that direction, by combining with the bile. These experiments were performed at the Hôpital Saint Louis, in the course of the year XI.

Urea, combined with a certain quantity of oxygen, appears to form an acid peculiar to human urine, and which is the substance of the greater numbers of urinary calculi. It resembles urea, in this that its crystals, exposed to heat, give out carbonate of ammonia; but it differs essentially from it, by its ready concrescibility. It, in fact, crystallizes, every time the urine grows cold, and forms the greatest part of the urinary sediment.—This acid, so weak that several chemists have considered it to be a mere oxide, has been called by M. M. Fourcroy and Vauquelin, the *uric* acid. Among its distinguishing characters, may be mentioned its being insoluble in cold water; it is so fixed, that several thousand times its own weight of boiling water is required to dissolve it, hence it may be easy to account for its so frequently giving rise to urinary calculi; we may, indeed, wonder, that this complaint is not of more frequent occurrence, since a slight cooling of the urine is sufficient to cause a precipitation and crystallization of the urine. Thus, every time an extraneous substance drops into the bladder, it becomes the nucleus of a calculus, formed by the uric acid becoming concrete on the surface of this body, which is of a colder temperature. Quadrupeds are less frequently affected with urinary calculi, from the absence of the uric acid in their urine, and because carbonate of lime, of which, in those animals, such concretions are formed, is a salt decomposed with effervescence by the weaker acids, and several such acids are found in the urine.

Phosphorus, which may be considered as the result of a high degree of animalization, enters, in considerable proportions, into human urine. Besides the phophoric salts which it contains, there is always found a certain quantity of disengaged phosphoric acid, which holds in solution the calcareous phosphate, and gives to the urine its manifest acidity, when examined fresh, or shortly after it has been voided. It was from urine, that phosphorus was first obtained, by those who originally discovered it, and from that fluid, it has long been procured for the purposes of commerce. But it is seldom obtained from urine, since the discovery of the phosphoric acid in the earth of bones, has rendered the manufacture of phosphorus easier and less expensive. In the urine of frugivorous mammiferous animals, phosphoric salts have their place supplied by calcareous carbonate.

Certain substances impregnate the urine with a peculiar odour. It is well known, that if one remain a few minutes in a room newly painted with oil of turpentine, the urine, for some time afterwards, gives out a smell of violets; asparagus gives to the urine a very remarkable fetor.

XXXVIII. Besides the accidental varieties observed in the urine, varieties which cannot be determined, since the urine is never uniformly the same in its composition, and does not contain the same ingredients in the same person, at different times of the day, according to the quantity and quality of the food and drink, the exercise which has been taken, the affections of the mind which have been experienced, &c.; it constantly varies, according to the time which has elapsed since a meal, the age of the subject and the diseases under which he may labour.

Physiologists have, for a long while, admitted two and even three different kinds of urine, according to the time at which it is voided; they are distinguished by the names of urine of the drink, urine of the chyle, and urine of the blood. The first is a limpid and nearly colourless fluid, which frequently retains, in a remarkable manner, the qualities of the drink, and is voided shortly after drinking, and has scarcely one of the characters of perfect urine. The urine of the chyle or of digestion, voided two or three hours after a meal, is more formed, still it is not perfect and does not contain all the component parts of this fluid.

Lastly, the urine of the blood which is voided, seven or eight hours after a meal, and in the morning after the night's rest, contains, in an eminent degree, all the qualities of urine, hence it is that which chemists prefer using in their analysis. The imperfect state of the two former kinds of urine, would prove better than the rapidity of their secretion, the disputed existence of a peculiar communication from the stomach and intestines into the bladder.

The urine of children and that of nurses contains very little phosphate of lime and phosphoric acid; it is only after the process of ossification is completed, that these elements abound in the urine. That of old men, on the other hand, contains a considerable quantity of these substances; their osseous system already containing phosphate of lime in excess, and incapable of receiving more, this saline substance would ossify all the tissues, as it sometimes does that of the arteries, the ligaments, the cartilages and membranes, if the urine did not carry off the greater part.

In the rickets, it is by the urine that the phosphate of lime is carried out of the system, and the absence of that susbtance is the cause of mollities ossium; on the approach of fits of the gout, the phosphoric ingredients of the urine diminish and seem to be carried to the joints, to produce in their vicinity arthritic concretions.

The great quantity of saline and crystallizable elements which enter into human urine, accounts for the frequency of the concretions which form in that fluid. Urinary calculi were long considered as formed of a single substance, which the ancients thought analogous to the earth of the bones, and which Scheele took for uric acid. The late investigations of M. M. Fourcroy and Vauquelin have shewn, that the component parts of urine are too numerous and too complex to produce uniformly calculi of one kind: that urinary concretions, most frequently formed from uric acid, contain urate of ammonia, phosphate of lime, phosphate of ammonia and magnesia, oxalate of lime, silex, and that these substances, singly, or in binary and ternary combinations, form the materials of nearly six hundred calculi which they analysed. Notwithstanding the extent of these researches, there is reason to believe, that when carried further by the same chemists, they will be attended with results still more varied. For, as there is no integral molecule in the body which may not be voided with the urine, and be found in the urine, so it is conceivable, that under certain circumstances which it is impossible to assign or to foresee, every thing in the human body that is capable of concretion, might supply the materials of urinary concretions.

This variety of elements in the composition of urinary calculi, the absence of signs, by which to ascertain their nature, the sensibility of the parietes of the bladder which would be irritated by agents capable of dissolving the concretions so frequently formed in its cavity, must render it very difficult, not to say impossible, to discover a lithontriptic which should supersede the necessity of a surgical operation, whose difficulties and danger have been much over-rated.

XXXIX. The energy of the urinary system in the inhabitants of temperate climates, has been considered as the cause of the frequency of calculous affections in Holland, England, and France, while they are very rare in more southern countries, in which the cutaneous perspiration seems to be substituted, in great measure, to the urinary secretion. There is no part of the world in which cases of stone in the bladder are more frequent than in England, and especially in Holland, in which a cold and damp atmosphere is unfavourable to perspiration, which is, at any rate, but scanty in persons of a leucophlegmatic temperament like that of the Dutch. In no other country, could a lithotomist (Raw) have operated on more than fifteen hundred patients, it is said, successfully. Diabetes, or an immoderate discharge of urine, a disease which appears to depend on an excessive relaxation of the renal tissue, is of frequent occurrence only in cold and damp countries, as Holland, England, and Scotland; it is more rare in France and Germany, and is unknown in warm climates. This relaxation of the renal tissue in diabetes, depends on the exhaustion of the urinary organs called into too frequent action, as is proved by the efficacy of tonics and astringents in the treatment of that complaint.

Cutaneous affections, on the contrary, seem to belong to the inhabitants of southern countries. Lepra originated in Judea, the elephantiasis rubra of Cayenne, the frambœsia of Java, the yaws, elephantiasis, herpetic and psoric eruptions, are more frequent among the inhabitants of southern latitudes, than among those who live under the temperate zones. In countries near to the equator, the surface of the body, habitually exposed to an ardent atmosphere, is powerfully excited; the skin is irritated, and its secretion increased; perspiration becomes so profuse, that it weakens, in a short time, those, who coming from distant countries, are not accustomed to so intense a heat. The activity of the cutaneous system exceeds that of the urinary system, whose action decreases in proportion. These differences in the energy of the two systems, account readily for the difference of their diseases: for, it is a law of Nature, that the more an organ, or system of organs, is called into action, the more it is liable to disease, which is but a derangement of its action.

Calculous affections are more frequent in children and old people, than in adults. In old age, the proportionate quantity of the urine exceeds that of the perspiration. Phosphoric salts, the base of a great number of urinary calculi, are more abundant in old men, as is proved in them by the ossification of the arteries, of the ligaments, of the cartilages, of the membranes, the solidification and the almost universal induration of the different parts. In children, the activity of the urinary system is proportionate to that of the digestive organs. Destined to throw out the residue of nutrition, which, at that period, is very active, the organs by which the urine is secreted are likewise endowed with considerable energy. Lastly, it is observed, that the greatest number of calculous patients received into the hospitals of large towns, come from low and damp streets near to rivers; every thing, therefore, tends evidently to establish, that the frequency of urinary calculi, depends on an increase of activity, in the organs destined to the secretion and excretion of urine.

CHAPTER II.

OF ABSORPTION.

XL. In the history of the phenomena of life, a statement of the functions of the absorbent system, ought immediately to follow that of the functions of the digestive organs. The vessels, which take up the chyle separated from the food, by the action of the organs of digestion, form a considerable part of the absorbent system, bear a perfect resemblance to the other lymphatics, and differ from them only in their origin. When digestion is not going on, those vessels convey lymph absorbed in the intestinal canal, the inner part of which, even when in a state of emptiness, is always bedewed by an abundant quantity of serous mucus.

There exist in all the parts of the human body, in the interior, as well as on the surface of our organs, vessels whose office it is to absorb, and to carry into the mass of the blood, those substances by which our machine is maintained and kept in repair, as well as what comes off in the continual destruction of our parts; for, it must not be forgotten, that the organized and living machine, inwardly acted upon by a double impulse, is perpetually undergoing decay and renovation.

XLI. Absorption is effected on substances introduced from without; such is the absorption from the skin, and the absorption of the chyle, &c. At other times, absorption takes place in fluids effused by arterial transudation; such is the serosity which moistens the serous membranes, the fat, the marrow of the bones, and this absorption, almost always, bears a proportion to transudation, so that the serosity, absorbed as fast as it is effused on the surface of the membranes which lie in close contact, except in cases of dropsy, never accumulates so as to separate those membranes. Finally, there is a kind of absorption, which may be termed nutritive or molecular, because it exerts its influence on molecules, which, in the process of nutrition, are separated from the organs and replaced by others. It is this absorption which brings about the decomposition of organs, and to which John Hunter gave the name of interstitial absorption. By means of it, the thymus, so voluminous in the fœtus, disappears entirely in the adult. This absorption seems to be incessantly going on, and to carry on decomposition, with a force that cannot be resisted. It explains, in a satisfactory manner, the spontaneous erosions of the living solids, of which ulceration* is the consequence.—M. Dumas has endeavoured to explain, in this way, the sensation of hunger, which, in the opinion of that physician, is felt when the absorbents exert on the solid coats of the stomach, their activity previously employed in taking up liquids. But to give even a degree of probability to that supposition which is entirely gratuitous, it would be necessary to shew, that the parietes of the stomach had been found destroyed or thinned, in persons who have died of hunger. The parietes of the stomach of such persons, have, on the contrary, been found thickened and in a state of contraction. This inward absorption is promoted by inflammation, hence the advantage of applying heat to indolent tumours, and of exciting a slight inflammation in swollen glands, in order to bring about resolution. It is on that account, that in swelling and induration of the testicle, unattended by cancer of the part, the operation for hydrocele by injection, may be safely employed.—Of this I had a convincing proof, a few years ago: a gardener, born deaf and dumb, had had for some years an hydrocele, which he was in the habit of getting tapped, every six months. When I last tapped it, I found the testicle swollen and hard, and three times larger than in its natural state, the patient, however, was free from pain. A considerable quantity of a reddish serous fluid was discharged; at the end of two days, inflammation of the tunica vaginalis came on, the scrotum became enlarged and was covered with emollient poultices. At the end of twenty days, the testicle was a good deal lessened in size and adhered to the inside of the tunica vaginalis: the cure was considered radical and proved such; for, though it is now ten years since the operation was performed, the water has not collected and the patient continues in the laborious employments of his business. I frequently meet him, and he never fails, by inarticulate sounds and signs of satisfaction, to express to me his gratitude.

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* *Nosographie Chirurgicale*, tome I. art. *Ulceres Atoniques.*

The process of absorption, is very active in children, in women, during sleep, in the morning, when the body is refreshed by the night's rest. Is a state of weakness favourable or unfavourable to that process? It is well known, that there are robust men who have intercourse with women infected with the venereal virus, and who escape the contagion, unless they expose themselves to it, when debilitated by excesses. A mind free of fear and anxiety, has ever been considered in the Eastern countries, a safe guard against the plague. A dog, cæteris paribus, is in much less danger from the bite of a viper, when suddenly bitten, than when he has been some time gazing at the reptile, and, more or less, terrified by the sight. But in all these cases, does debility favour the introduction of the contagious matter, by increasing the force of absorption; or is it not more probable, that by affecting the nervous system, it renders it more susceptible of deleterious impressions?

XLII. Absorption is much less active, on the external surface of the body, than on the surface of its internal cavities, and in the very substance of our organs. Cutaneous absorption, under certain circumstances, has even so litte activity, as to have led some physiologists to doubt its existence. The absorbing orifices of vessels which arise on the surface of the body, are covered by the epidermis. This covering, which is insensible, and, as it were, inorganic, forms a sort of separation, between the external and internal part of our being, and opposes, or renders more difficult, the absorption of substances in immediate contact with our body, and if it be considered, that we are frequently immersed in the midst of gases and other substances, to a certain degree, deleterious, it will be understood, how essential it was, that the absorbing surface of the skin, should not be entirely exposed, and that cutaneous absorption should not be easily carried on.

The increased weight of the body, after exercise in wet weather; the abundant secretion of urine, after remaining long in the bath; the manifest enlargement of the glands of the groin, after keeping the feet immersed, for a considerable time, in water, an experiment often performed by Mascagni on himself; the effects of mercurial frictions, &c. shew, however, in an unquestionable manner, that absorption takes place through the skin, with more or less rapidity, according to circumstances. It must be taken into account, that the means which promote cutaneous absorption, operate, at least as much, by altering the structure of the epidermis, as by increasing the action of the absorbing orifices. In this manner, the bath appears to operate, by softening the texture of the epidermis; and frictions, by displacing and raising its scales.

It is by means of frictions, that we succeed in introducing into the lymphatic system, medicines possessing purgative, febrifuge, sedative, or diuretic qualities, combined with the gastric juice, or diluted in any other liquids, for, as has been shewn by the experiments performed at the Salpetriere, by M. M. Dumeril and Alibert, in the name of the Philomatic Society, the mixture with saliva or gastric juice, of the medicines which are to be administered by friction, is not necessary to insure their absorption. Extract of opium has soothed pain, bark has checked fits of intermittent fever, rhubarb has procured alvine evacuations; squills have stimulated powerfully the action of the urinary organs, nor has the previous mixture, with gastric juice, of these substances reduced into powder, seemed to increase or diminish their efficacy.

Absorption takes place quickly and readily, wherever the epidermis is thin, habitually moist, and the skin delicate, so as to leave almost bare of covering, the subjacent parts, as on the lips, in the inside of the mouth, on the surface of the glans, &c. The complete removal of the epidermis, favours absorption from all parts of the skin which it covered.—Hence the least scratch on the fingers of an accoucheur touching women infected with the venereal virus, exposes him to this peculiar infection, which, in such cases, is the more to be dreaded, from the admission of the virus by an unusual course. The inoculation of variolous and vaccine matter, equally furnishes proofs of the obstacle which the epidermis presents to cutaneous absorption, and of the facility with which that function takes place, from surfaces denuded of that covering. Absorption goes on, likewise, with great activity, from the surfaces of internal parts, but it no where is so considerable, as in the intestinal canal, and it would perhaps be the most favourable part for introducing medicinal substances into the animal economy, if when swallowed, they did not undergo changes, by mixing with the gastric juices, or with the intestinal fluids and fæcal substances, when injected by the rectum. From the evacuation by urine of clysters of warm water, soon after they have been administered, it is to be presumed, that the great intestines absorb, almost as powerfully as the rest of the digestive canal. A pint of warm water injected into the abdomen of a large dog or sheep, is often absorbed in less than an hour, and the effusions which take place in those cavities, would possibly not require an operation to let them out, if such fluids were not subject to coagulation, and if the absorbing surfaces were not diseased.

Besides absorption from surfaces, there exists, as we have already stated, another which takes place in the living solid, and in the internal substance of the organs. It is by this kind of absorption, that the nutritive decomposition is effected; by means of it, the living matter is incessantly renovated. Its vitiated action accounts for the spontaneous formation of ulcers, the disappearing of the thymus, the atrophy of parts in which nutrition is carried on, in a sluggish manner; the resolution of certain tumours, and many other phenomena, are dependent on the same cause.

I do not think, however, that it is possible to admit the explanation of the sensation of hunger, adopted by Professor Dumas, who believes that it depends on the action of the absorbing orifices directed against the organized substance of the stomach, in the absence of aliment on which to act. The sensation of hunger is felt only in the stomach, although its effects extend to all parts of the body; it begins in a circumscribed spot, its seat is limited, yet absorption takes place every where, so that if the hypothesis in question had any foundation, the sensation of hunger ought to be felt at the heel, as well as at the pit of the stomach.*

The radicles from which the lymphatics arise, have orifices so very minute, that they are imperceptible to the naked eye; a tolerably accurate notion may be formed of them, by comparing them to the puncta lachrymalia, which are larger and more easily discovered. Each orifice endowed with sensibility, and with a peculiar power of contraction, dilates or contracts, absorbs or rejects, according as it is affected by the substances which are applied to it. The variations of the aborbing power, according to the age, the sex, the constitution, and different periods of the day, shew that it cannot be compared, as several physiologists have done, to that principle which makes fluids ascend, contrary to the laws of gravitation, in capillary tubes. If absorption were a process merely mechanical, it would, in no case, be accelerated or retarded, and would proceed with a regularity never observed in the vital functions. The mouth of every lymphatic, when about to absorb, erects itself, draws towards itself, and raises the surrounding membranous parts, and thus forms a small tubercle similar to the puncta lachrymalia. These little bulgings deceived Lieberkuhn, and led him to think, that the absorbents of the intestines originated from small ampullulæ, or vesicular enlargements, which, as so many exhausted receivers, pumped up the fluid extracted from the food. This physiologist may, further, have been led into error, by the nervous papillæ of the inner membrane of the canal, swollen by the determination of blood attending irritation, the natural consequence of the friction of the alimentary substances. The inhaling faculty belongs, not only to the orifices at the extremity of each radicle, but, likewise, to the lateral pores, which are infinitely numerous, in the parietes of the vessels.

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* It does not fall to the lot of every one, to err like M. Dumas, whose talents and ingenuity I have much pleasure in acknowledging. He imagines rickets to consist, in a deficient influence of the nervous system on the bones: which would constitute a kind of paralysis. Anatomy shews the presence of no nerves in the tissue of the bones, and veins and arteries are alone seen to enter the foramina, and no nerves appear to be transmitted through them. The functions of the bones made it unnecessary, that they should be endowed with that peculiar sensibility which requires the existence of nerves. The bones are active by being subject to the process of nutrition, but in every other respect, they are absolutely passive. In the opinion of some people, such doctrines are real discoveries. *Credat judæus Apella, non ego.*

XLIII. After arising on the surface, and in the interior of the body, by radicles in close contact, the lymphatics creep and coil themselves, describe numerous curves, unite, then divide, and presently unite again, and from these numerous inosculations, there results a net-work, with close meshes, forming, with that of the blood vessels, the texture of the cellular tissue and of the membranes.

Each lamina of cellular tissue is, in the opinion of Mascagni, nothing but a mesh-work of lymphatics—the texture of the membranous and transparent tissues, as the pleura and the peritoneum, resembles that of the laminæ of the cellular tissue; in fine, the same vessels form the basis of the mucous membranes which line the internal parts of the alimentary canal, of the trachea and urethra. The Italian anatomist succeeded, in filling, with quicksilver, all the tissues which he considered as lymphatic; but Ruysch, in his admirable injections, reduced all the membranes, and the laminæ of the adipose tissue, into a net-work purely arterial, of which the meshes were so very closely united, as to leave spaces that could scarcely be perceived by the microscope, and from his preparations he inferred, that arterial capillary vessels, singularly divided and convoluted, form the basis of cellular and membranous tissues. To satisfy oneself, that neither the pleura nor the peritoneum are formed as Mascagni or Ruysch imagined, one need only consider, that arterial exhalation and lymphatic absorption take place, from the whole extent of the internal surfaces, and that these two functions prove the existence of both arteries and absorbents, in those membranes and in the cellular tissue. The prejudices of those two anatomists, so celebrated, the one by his study of the absorbents, and the other by his beautiful injections of the most minute arteries, are to be attributed to the importance which we are pleased to assign to the objects which particularly engage our attention, and likewise to the distention of the minute vessels by the injection; these being distended beyond their natural state, compress and conceal the neighbouring parts.

The lymphatics, after emerging from among the cellular substance, unite into trunks sufficiently large to be distinguished from the laminæ of that tissue. These trunks proceed towards certain parts of the body, there they become united to other trunks, follow a parallel course, and frequently communicate together. The lymphatics are not single in their course, as the arteries and veins; they collect together, form fasciculi of different sizes, some of which are deep seated and accompany the blood vessels, while others of them, are more superficial, corresponding to the subcutaneous veins of the limbs, and, like them, lying between the skin and the aponeuroses, and in greatest number, on the inner side of the limbs, in which they are best protected against external injuries. The lymphatics of the parietes of the great cavities, those of the viscera which these cavities contain, are likewise in two layers, the one superficial, the other deep seated.

The absorbents differ, likewise, from the blood vessels, in their singularly tortuous course, their frequent communications, and especially in their unequal size in different parts of their extent. An absorbent, of very small dimensions, frequently enlarges, so as to equal in size the thoracic duct, then contracts and again bulges out, though in the length of the vessel in which these differences of size may have been noticed, it may have received no collateral branches. The lymphatics, when completely filled with quicksilver, appear to cover the whole surface of our organs: and the whole body seems enveloped in a net-work of close and small meshes. The metastasis of humours, from one part of the body to another at a distance, is easily understood by any one who has seen those numerous inosculations, rendered manifest by injection. Metastasis ceases to be an inexplicable phenomenon; one has no difficulty in conceiving, how by means of the lymphatics, all the parts of the body communicate freely; how, fluids absorbed by those vessels in one part, may be conveyed into another, and pervade the whole body, without following the circuitous route of the circulation, and that it is, therefore, not altogether impossible, however improbable, that fluids taken into the stomach, may be conveyed directly from the stomach to the bladder, and, that in the same manner, the milk of the intestinal canal may find its way into the breasts; and that pus may be removed from the place in which it is collected, and be conveyed to the place to which irritation calls it forth. All that Bordeu has said of the oscillations and currents of humours, through the cellular texture, in his "*Recherches sur le Tissu mu-*

queux," may be equally explained by the anastomosis of the lymphatics.

A young man whom I had ordered to rub in mercury, along the inner part of his left leg and thigh, for the cure of a pretty large bubo, was affected, on the third day, with salivation, though he used only half a dram of ointment, at each friction. The salivary glands of the left side, were alone swollen, the left side of the tongue was covered with aphthæ, and the right side of the body remained unaffected by the mercurial action; a clear proof, that the mercury had been carried to the mouth, along the left side of the body, without entering into the course of the circulation, and perhaps, without passing through any of the conglobate glands; for, that of the left groin, which alone was swollen, did not sensibly diminish in size. Salivation may, therefore, take place, in the cure of the venereal disease, though none of the mercury enter the circulation, which warrants the opinion, that the action of syphilis, as well as of the remedies which are administered for its removal, operates chiefly on the lymphatic system.

XLIV. If the fluids absorbed by these vessels, can, in consequence of their numerous inosculations, pervade all parts of the body, without mixing with the blood, not a drop can enter the course of the circulation, without having previously passed through the glandular bodies that lie in the course of the lymphatics; dispersed like those vessels in all parts of the body, seldom insulated, but in clusters in the hollows of the ham, the arm-pit, in the bends of the groin and elbow, along the iliac vessels, the aorta and the blood vessels of the neck, around the base of the jaw and of the occiput, behind the sternum, along the internal mammary vessels, lastly, within the mesentery, in which their number and size bear a proportion to the quantity of absorbents which pass through them. These reddish glands*, varying in size, of an oval or globular form, have two extremities, the one at which the lymphatics enter, they are then called "*afferentia,*" and the other extremity turned towards the thoracic duct, which sends out vessels, fewer in number, but of a larger size, and called "*efferentia*" from their use.

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* It is with a view of conforming to the language in common use, that I give the name of gland to those coils of lymphatic vessels, which are totally different from the real conglomerate or secretory glands. It might be better, perhaps, to call them *ganglions*, as has been done by my learned and respected colleague Chaussier, though that name is objectionable, from its association in the mind with the nervous ganglions, whose structure is not at all similar to that of the lymphatic ganglions.

The lymphatics, on reaching the glands, divide, unite again and insoculate, they likewise bend back on themselves, and thus form the tissue of the conglobate glands, which are merely clusters of coiled vessels, united by cellular tissue; in which blood vessels are distributed, so as to occasion their reddish colour. The coats of the lymphatics are thinner in the glands than elsewhere; and their dilatations, their divisions, and their anastomoses are likewise more frequent, while they are in the glandular tissue. All the lymphatic vessels, whose course lies in the direction of a gland, do not enter its substance, several pass by the gland and embrace it, forming around it a sort of plexus, of which the ramifications are directed towards other glands, more in the vicinity of the thoracic duct. The lymphatic glands form so essential a part of the absorbent system, they produce on the lymph such indispensable charges, that no lymphatic vessel enters the thoracic duct, without having previously passed through these glands. It even frequently happens, that the same vessel passes through several glands, before opening into that common centre of the lymphatic system. Thus, the vessels which absorb the chyle of the intestinal tube, pass several times through the glands of the mesentery.—The lymphatics of the liver, situated very near to the receptaculum of Pecquet, have been thought, by some anatomists, not to follow that general rule; but there are uniformly found, in the course of these vessels, glands which they enter. As, however, the glands are few in number, the lymph conveyed from the liver, is only once subjected to the action of the glands; and this circumstance appears to me to explain, in a satisfactory manner, the transmission of the colouring matter of the bile, which, in jaundice, manifestly discolours the blood, in which M. Deyeux found it by chemical analysis.

XLV. The parietes of the lymphatic vessels are formed of two coats, both very thin and transparent, yet very strong, since they support the weight of a column of mercury, which would rupture the coats of arteries of the same caliber. The internal coat, which is the thinner of the two, forms valvular folds, arranged in pairs, like the valves of the veins, and like them preventing a retrograde circulation.—Although these coats are very strong, and likewise very elastic and contractile, as they may be seen to contract, and to expel the lymph with great impetus, when the abdomen of a living animal* is laid open, yet the course of the lymph is far from being as rapid as that of the blood; it even frequently appears affected with irregular oscillations, such as are to be met with in the circulation of the blood through the capillary arteries. The numerous dilatations, curvatures and anastomoses of the absorbents must, in a considerable degree, impede the rapid progress of the lymph, but the circulation must be retarded, chiefly in the glands, as there the vessels are most convoluted, dilated, and form the greatest number of anastomoses, and are most subdivided. Besides, the parietes of the absorbents are thinnest in their passage through the glands, for, these may be ruptured by the weight of a column of mercury which the vessels themselves are able to support. And the action of these vessels, naturally weaker in that situation, is still farther diminished, by the close cellular adhesion which unites together the vessels whose union forms the glandular bodies.

It was necessary that the course of the lymph should be slackened in its passage through the glands, in order that it might undergo all the changes which those organs are to produce upon it. Although we do not know precisely, what those changes are, their object appears to consist in a more perfect union and combination of its elements, and in bestowing on it a certain degree of animalization, as is seen, by the greater tendency to coagulation of the fluid taken from the vasa efferentia. Another object of the passage of the lymph through the glands, appears to be to deprive it of its heterogeneous particles, or at least to alter their nature, so that they may not become injurious, when they get into the mass of the fluids. The yellow colour of the glands through which the absorbents of the liver pass, the dark colour of the bronchial glands, the red colour of the mesenteric glands, in animals which have been fed on madder or beet-root, the whiteness of the same glands, while the chyle is passing through them, are circumstances which shew, that the glands separate, or tend to separate, the colouring matter of the lymph, and that if they do not effectually prevent its transmission into the blood, it is because certain colours, as indigo and madder, have too much tenacity, while other substances, as the bile, do not pass through a sufficient number of glands, to lose their colour entirely. The blood vessels, which are very numerous in the tissue of the conglobate glands, pour, into the lymphatics a serous fluid which dilutes the lymph, increases its quantity, and at the same time time, animalizes it. The number of the lymphatic glands is very great; many are so small as to escape the eye, but become enlarged and visible, in certain cases of disease.—I have daily opportunities of observing in scrophulous patients, swollen glands, in situations in which anatomists have not pointed out any. The absorbent glands are, at no time, so large or numerous as in infancy. They very frequently disappear in old people, and it is difficult to say, whether they have been totally destroyed, or whether they are merely exceedingly reduced in bulk.

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* In some cases, the activity of the absorbents appears increased, in a singular degree. Thus, jaundice has been known to be the immediate consequence of a wound of the liver; and on other occasions, a metastasis of humours has taken place, with the utmost rapidity. I suspect, that, in such cases, the substance that has been absorbed, circulates by means of the anastomoses, and pervades the lymphatics with which the whole body is covered, but without passing through the glands, which would slacken its course, and, to a certain degree, alter its nature.

XLVI. The frequent congestions of the conglobate glands, depend on the stagnation of the lymphatic fluid in their substance, and on the comparative weakness of the sides of the vessels in these parts. The influence of debilitating causes on the lymphatic system, acts most powerfully on the glands, which are the weakest part of that system. In such cases, the vessels which enter into the composition of the glands, act feebly, or cease to act altogether; the fluids, of which there is a continual accession, accumulate; the most liquid part alone penetrates through the glandular organ, the grosser particles remain, the humour thickens, hardens, and forms congestions of various kinds. If there is a tendency to cancer, such tumours, at first indolent, become painful, the indurated matter being, in a manner, out of the influence of the vital power, since its vessels are in a state of compleat atony, undergoes a sort of putrid fermentation, the consequence of which is a destruction and erosion of the cellular tissue, attended by inflammation of the skin and neighbouring parts. The tumour becomes an abscess, and discharges matter rendered liquid by the process of fermentation, and so acrid and irritating, that it extends the affection towards all the parts with which it comes in contact.

The notions entertained hitherto on cancer, are, at once, deficient in precision and accuracy, and it is to their fallacy, that we are to attribute the number of contradictory opinions on the subject of its proper treatment. Too precise a distinction cannot be laid down; between the cancerous or phagedenic ulcer, whose seat is always in the skin, or in the mucous membranes (which being mere prolongations of the skin, retain much of its structure), and those cancers which affect the other parts of the animal economy, especially the lymphatic glands, the testicles and the breasts. In the cancerous ulcers, peculiarly frequent in the face, the lips, the tongue, in the inner coat of the stomach, of the rectum, and of the uterus, the parts, affected with inflammation of a malignant kind, are destroyed, without any means of checking the progress of that destructive action, the cause of which is easily conceived, while in true cancer, the glandular tumefaction always precedes the cancerous diathesis. As long as the affection consists merely in the obstruction of the vessels by indurated lymph, the tumour is indolent, and is yet only a schirrus; but soon all trace of organization is lost in the tumefied part, the ruptured vessels are lost in the mass of different substances; the process of fermentation which takes places, converts every part into a grayish pulpy substance, in which the most expert eye can discover no organization, and no distinction of parts. Whenever this cancerous destruction of parts occurs, whether the whole organ is affected, or whether the disease extends only to a few points, extirpation is the only remedy to be employed; it is absolutely necessary, that a surgical operation should rid the constitution of a part, in which organization and life no longer exist.'

The lymphatic glands which swell in the vicinity of cancerous tumours, have already received, by means of the absorbents, the destructive germ, and must be removed, with the rest of the diseased part, that the operation may be attended with the greater prospect of success. It is very true, that open cancers of the breast may, for a long time, discharge putrid matter, without inducing a cancerous affection of the glands of the axilla. But may not the discharge, in this case, act on the principle of revulsion; and besides, what shall we oppose to experience, which shews that these glands, if not removed along with the cancerous breast, soon become affected with cancer. If the nature of this work did not circumscribe me, within certain limits, I should point out several other particulars relative to the history of cancer, and among other cases, in my own practice, I should relate that of a woman, in whom I removed a cancerous tumour situated on the left side of the chest; this case is remarkable from the number of operations which her disease required, and for which M. Pelletan removed, six years ago, the left breast, and, three years ago, a gland under the axilla of the same side.

The difference in the termination of glandular swellings and those arising from cancer, scrophula, or syphilis, makes it probable, that there exist ferments, or specific poisons, which dispose the accumulated matter to undergo peculiar changes.

The venereal virus, absorbed by the lymphatics of the organs of generation, remains, for some time, in the glands of the groin, before it extends beyond, as is proved by the cure of the venereal disease, by extirpating the diseased glands. In short, the impediment which the lymph meets with, in passing through the glands, shews why these parts are so frequently the seat of critical abscesses, by which we judge of the nature of several fevers of a malignant kind. In the plague of Eastern countries, the virus that occasions this dreadful malady, is disseminated throughout the body, collects in the glands, is transmitted through them with difficulty, brings on an irritation and gangrenous inflammation, terminating in pestilential buboes.

XLVII. The thoracic duct may be considered as the centre in which the whole lymphatic system terminates; it arises at the upper part of the abdomen, from the union of the chylous vessels with the lymphatics coming from the inferior extremities. At the part where all these vessels meet, there is a dilatation, a sort of ampullula, called lumbar cistern, receptaculum chyli, or of Pecquet, which, in truth, is not always found, and the size of which is very variable. The thoracic duct enters the chest, through the opening in the diaphragm which transmits the aorta, it then ascends along the spine, on the right side of the aorta, within the posterior mediastinum. At the upper part of the chest, opposite to the seventh cervical vertebra, it inclines from the right to the left side, passes behind the œsophagus and the trachea, and opens into the subclavian vein of the left side, at the back part of the insertion of the internal jugular into that vein. While the thoracic duct is ascending along the spine, it receives the lymphatics of the parietes of the chest; those of the lungs enter it as it passes behind the root of these organs. In its course from the right towards the left side, it receives the absorbents of the right upper extremity, and those of the right side of the head and neck. Lastly, it unites with those vessels which are coming from the left side of the head and neck, as well as from the left upper extremity, just before opening into the subclavian vein. The thoracic duct sometimes has its insertion in the jugular vein of the same side, and not unfrequently the lymphatics of the right side of the chest, neck, and head, and of the right upper extremity, unite to form a second duct, which opens separately into the right subclavian vein.* Whatever be the vein into which the duct opens, its structure is the same as that of the lymphatics, and its inner part is furnished with valvular folds. Its increase of size is not progressive, as it approaches towards its termination; on the contrary, there are seen, here and there, dilatations of different sizes, separated by proportionate contractions. Sometimes, it divides into several vessels which inosculate and form lymphatic plexuses. The opening at which the thoracic duct enters the subclavian vein, is furnished with a valve, better calculated to prevent the flow of blood into the lymphatic system, than to moderate the too rapid flow of the lymph into the torrent of circulation. Compression of the thoracic duct, in aneurism of the heart and aorta, gives rise to several kinds of dropsy, a disease always depending on the loss of equilibrium, between the processes of inhalation and exhalation, either from increased action of the exhalants, or from the absorbents refusing to take up the lymph, in consequence of obstruction in the glands, or of compression of the duct.

XLVIII. The nature of the lymph is far from being as well understood, as that of the vessels along which it circulates. Haller considers it as very analogous to the serum of the blood, and says that this substance, to which he frequently gives the name of lymph, is like the fluid contained in the absorbents, slightly viscous and saltish; that heat, alcohol, and the acids coagulate it, in short, that it possesses all the qualities of the albuminous fluids. The serum of the blood exhaled, thoughout the extent of the internal surfaces, and even, within the substance of our organs, by the capillary arteries, is absorbed by the lymphatics, and is one of the principal sources of the lymph, which resembles it much. It may be conceived, however, that the nature of the lymph must be much more compound than that of the serum of the blood, since the lymphatics which absorb, almost indiscriminately, every kind of substance, take up what comes off from our organs, and the recrementitious parts of our fluids, and these are some times recognizable in the absorbents, when marked by striking qualities, as fat by its not mixing with aqueous fluids, and bile by its deep yellow colour.

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* In some rare cases, lymphatic vessels, in other parts of the body, are seen to open into neighbouring veins. This enables one to account for the presence of the chyle which is said to have been found in the meseraic veins, into which it had been poured by some lacteal. Mascagni was aware of this anatomical fact. The lymphatic system is, however, the most subject to deviations of any in the animal economy.

The chyle, which is necessarily affected, by the various kinds of food which we use, has different appearances in the same persons, varying according to the quality of the different substances on which we feed; indigo gives it a blue colour; it is reddened by madder and beet root, and is changed to green, by the colouring matter of several vegetables, &c. In a great number of experiments performed on living animals, it has always appeared to me, such as it is described by authors, white, with a slight viscidity and very like milk containing a very small quantity of flour. It is easy to collect a certain quantity of chyle, by tying the thoracic duct of a large dog, of a sheep, or even of a horse, as was done, several times, at the veterinary school at Alfort. This fluid, when exposed to the air, on cooling, separates into two parts, the one forming a kind of gelatinous coagulum, very thin and not unlike the buffy coat of inflammatory blood; the other, in greater quantity and liquid, rising above the coagulum, on its being detached from the sides of the cup to which it adheres. The coagulated mass is semi-transparent, of a light pink colour, does not resemble the curd of milk, so that all that has been said by a few modern physiologists, on the exact resemblance which they have pretended to discover between milk and chyle, is totally void of foundation.

The lymph, which constantly unites with the chyle, before the latter enters the sanguiferous system, on being received into a vessel by Mascagni, coagulated in the space of seven or ten minutes, turned sour, and soon separated into two parts, the one more abundant, serous, in the midst of which there floated a fibrous coagulum, which by contracting, formed into a small cake on the surface of the fluid. Hence he concludes, contrary to the opinion of Hewson, that lymph consists, for the greatest part, of serum, and that fibrine constitutes its least part.

XLIX. The practice of surgery in a great hospital, has afforded me frequent opportunities of examining the lymph which is discharged, in abundance, from ulcerated scrophulous tumours, in the groin, in the axilla, and in various other parts of the body. I have always met with a liquid nearly transparent, slightly saline, coagulable by heat, alcohol and the acids. Small fibrous flocculi form, even on the surface of the cloths which are wetted with it, and shew the existence of two parts, the one a gelatino-albuminous fluid holding in solution several salts, the other, in smaller quantity, is a fibrous substance which concretes spontaneously. The lymph, in man and the warm-blooded animals, appears to me, in very respect, similar to the fluid which is contained in the vessels of white blooded animals.

CHAPTER III.

ON THE CIRCULATION.

I. The term circulation is applied to that motion by which the blood setting out from the heart, is incessantly carried to all parts of the body by means of the arteries, and returns, by the veins, to the centre whence it began its circuit.

The uses of this circulatory motion, are to expose the blood changed by mixing with the lymph and the chyle, to the air in the lungs (*Respiration*), to convey it to several viscera in which it passes through different steps of purification (*secretions*); and to send it into the organs whose growth is to be promoted, or whose losses are to be repaired, by the nutritive and animalized part of the blood brought into a state of perfection, by these successive processes (*nutrition*).

The circulatory organs are less useful in elaborating, than in conveying the fluids. To form a just conception of their uses, one may compare them to those workmen in a large manufactory in which various kinds of goods are made, who are employed in carrying the materials to those who are to work them; and as among the latter, some finish the work, while others prepare the materials, so the lungs and the secretory glands are continually occupied in separating from the blood, whatever is too heterogeneous to our nature to become assimilated to our organs, or to afford them nourishment.

To understand, thoroughly, the mechanism of this function, it is necessary to study separately the action of the heart, that of the arteries which arise from it, and lastly that of the veins which enter it. The union of these three classes of organs, forms the circle of the circulation.

LI. *Of the action of the heart.* In man and in all warm-blooded animals, the heart is a hollow muscle, the inner part of which is divided into four large cavities which communicate with one another; from these, vessels arise which convey the blood to all parts of the body, and the vessels which bring it back from all those parts, likewise terminate in these cavities.

The heart is placed in the chest, between the lungs, above the diaphragm whose motions it follows; it is surrounded by the pericardium, a dense and fibrous membrane admitting of very slight extension, closely united to the substance of the diaphragm, covering the heart and great vessels, without containing them in its cavity, furnishing an external covering to the heart and bedewing its surface with a serous fluid, which never accumulating, except in disease, facilitates its motion, and prevents its adhering to the neighbouring parts. The principal use of the pericardium, is to fix the heart in its place, to prevent its being displaced into other parts of the chest, which could not happen, without occasioning a fatal disorder in the circulation. If, after having laid open the chest of a living animal, by raising the sternum, an incision is made into the pericardium, the heart protrudes through the opening, and moves to the right and left by bending itself on the origin of the large vessels; the course of the blood is then intercepted, and the animal threatened with immediate suffocation.

In man, the heart is placed nearly towards the union of the upper third of the body, with the lower two thirds; it is, therefore, nearer to the upper parts; it holds them under a more immediate controul, and as that organ keeps up the action of all the rest, by the blood which it sends into them, the parts above the diaphragm, have much more vitality than the parts beneath. The skin of the upper part of the body, and especially of the face, has more colour, and is warmer than that of the lower parts; the phenomena of disease come on more rapidly in the upper parts; they are, however, less liable to put on a chronic character.

The bulk of the heart, compared to that of other parts, is larger in the fœtus, than in the child that has breathed, in short men, than in those of high stature. The heart is likewise larger, the stronger, and more powerful in courageous animals than in weak and timid creatures.

This is the first instance of a moral quality depending on a physical disposition of parts; it is one of the most striking proofs of the influence of the moral character of man, on his physical nature. Courage arises out of the consciousness of strength, and the latter is in proportion to the activity with which the heart propels the blood towards all the organs. The inward sensation occasioned by the afflux of the blood, is the more lively, and the better felt, when the heart is powerful. It is on that account that some passions, for example, anger, by increasing the action of the heart increase a hundred fold both the strength and courage, while fear produces an opposite effect. Every being that is feeble, is timorous, shuns danger, because an inward feeling warns him, that he does not possess sufficient strength to resist it. It may perhaps be objected, that some animals, as the turkey cock and the ostrich, posses less courage than the least bird of prey, that the ox has less than the lion and other carnivorous animals. What has been said does not apply to the absolute, but to the relative size of the heart. Now, though the heart of a hawk, be absolutely smaller than that of a turkey cock, it is nevertheless larger, in proportion to the other parts of the animal. Besides, the bird of prey, like the other carnivorous animals, in part owes his courage, to the strength of his weapons of offence.

Another objection, more specious, but not better founded, is drawn from the courage manifested, on certain occasions, by the most timid animals, for example, by the hen in protecting her young; from the courage with which other animals pressed by hunger or lust, surmount all obstacles, but particularly from the heroic valour of men of the most feeble bodies. All these facts, however, are only proofs of the influence of the mind on the body. In civilized man, the prejudices of honour, interested considerations, and a thousand other circumstances, degrade the natural inclinations of man, so as to make a coward of one whose strength is such as would induce him to brave all kinds of dangers, while on the other hand, men whose organization should render them most timid, are inspired to perform the most daring actions. But all these passions, all these moral affections operate, only by increasing the action of the heart, by increasing the frequency and the force of its pulsations, so that it excites the brain or the muscular system, by a more abundant supply of blood.

The heart is not quite ovoid in man as it is in several animals, nor is it parallel to the vertebral column, but it lies obliquely, and is flattened towards the side next the diaphragm on which it rests.

Of the four cavities which form the heart, two are, in a measure accessory, viz. the auricles; they are small musculo-membranous bags opposed to each other, receiving the blood of all the veins, and pouring that fluid into the ventricles at the base of which the auricles are, as it were, applied. The ventricles are two muscular bags separated by a partition of the same nature, and belonging equally to both: they form the greatest part of the heart and give origin to the arteries.

The auricle and ventricle on the right side, are larger than those on the left. But that difference of size depends as much on the manner in which the blood circulates, at the approach of death, as on the original conformation of the heart. On the point of death, the lungs expand with difficulty, and the blood sent into them, by the contractions of the right ventricle, being no longer able to circulate through them, collects in that cavity, flows back into the right auricle, in which the veins continue to deposit blood, stretches their parietes, and increases considerably the dimensions of those cavities. The capacity of the right cavities is, however, originally greater, than that of the left, and is proportioned to that of the venous system which opens into it. The right cavities of the heart, which might be called its venous cavities, have likewise thinner parietes than the left or arterial, and, in this respect, the same difference is observed, as in the parietes of the arteries and veins. The right ventricle having to send the blood destined to the lungs, to a very short distance, and through a tissue easily penetrated, requires but a moderate impelling force.

As will be shewn, in speaking of respiration, a function of which the physiological history is not easily separated from that of the circulation, the heart may further be considered, as formed of two parts in contact, the one right or venous, the other left of arterial. Notwithstanding the juxta position of these two parts of the same organ, they are perfectly distinct, and the blood in each cavity, is very different from that in the other. The blood, in the adult, can never pass immediately from the one to the other; the right side of the heart, receives the blood of the whole body and transmits it to the lungs; the left side of the heart, receives the blood of the lungs, and distributes it over the whole body, so that, in a physiological point of view, the lungs form a part of the circle of the circulation, and serve as an indispensable medium between the two divisions of the heart, and as will be seen hereafter, their part of the circle is, by no means, the least important.

If there existed, between the ventricles, a direct communication, the venous blood would mix with the arterial, and the union of these two fluids would mutually impair the qualities of each. Recent observations have furnished an opportunity of judging of the effects of such a communication between the ventricles, which had been imagined by the ancients, but of which no case had yet been met with. A man forty-one years of age, came to the Hôpital de la Charité, to undergo the operation of lithotomy. He was remarkable for the lividity of his complexion, the turgescence of the vessels of the conjunctiva, and the thickness of his lips, which, like the rest of his face, were of a dark colour, his respiration was laborious, his pulse irregular, he could not utter two words in succession, without taking breath; was obliged to sleep in a sitting posture, and was particularly remarkable for his indolence. This indolence, joined to great simplicity of nature, was such, that he had never been able to maintain himself, without the assistance of his wife. A very small quantity of blood was taken from his arm, in consequence of which, his pains were diminished, but his difficulty of breathing increased, was followed by syncope, and he died from suffocation. On opening his body, his heart was found filled with blood, and especially the right auricle, which was considerably distended; the pulmonary artery was aneurismal, and uniformly distended from the right ventricle, to its division; none of its coats had yet given way. The two ventricles of the heart were of nearly the same capacity, and the relative thickness of their parietes did not vary so much as in health. The partition between them, contained an opening of communication of an oblong shape, about half an inch in extent, and directed obliquely from below upwards, from before backward, and from left to right, so that, not only the direction of the opening, but likewise a kind of valve formed in the right ventricle, by a fleshy column, so placed as to prevent the return of the blood into the left ventricle; clearly shewed, that the blood flowed from the left into the right ventricle, and thence into the pulmonary artery. The ductus arteriosus, an inch in length, and large enough to admit a goose quill, allowed, as in the fœtus, a free passage to the blood, from the pulmonary artery into the aorta. The foramen ovale was closed.

This singular conformation explains, in the most satisfactory manner, the phenomena observed during the life of the patient, and the organic affection of the pulmonary artery. There was necessarily, in this vessel, a mixture of venous and arterial blood, and this blood was sent into it, in part by the action of the left ventricle, with an increased impetus, which accounts for the aneurism. The blood which reached the lungs was already vivified, and required less action from that organ, to complete its oxydation; on the other hand, the right auricle emptied itself, with difficulty, into the right ventricle, in part filled with the blood which the left ventricle sent into it with greater force: hence the extreme difficulty in the venous circulation, the lividity of the complexion, the colour and the puffiness of the face, the habitual and general torpor. This state of languor and inactivity might, likewise, depend on the flow of the venous blood into the aorta, along the ductus arteriosus. It is worthy of observation, however, that this impure blood was not transmitted to the brain, whose vital excitement it would not have been able to maintain. The lower extremities bore no proportion to the upper, and this inequality analagous to what is observed in the fœtus, depended on a similar cause. This morbid preparation, was deposited by M. Deschamps, in the museum of the Ecole de Médecine of Paris, and was, by their desire, modelled in wax. M. Beauchêne, junior, presented the same museum with a similar preparation, which he procured from a subject in the dissecting room.

Several anatomists have paid attention to the structure of the heart; much has been said on the subject of the peculiar arrangement of the muscular fibres which form its parietes, yet, the only result that can be obtained from all these researches is, that it is absolutely impossible to unravel the intricacy of these fibres. Fibres of the ordinary structure, and crossing each other, in various directions, form the two auricles; other and more numerous fibres form the parietes of the ventricles, reach from the apex to the base, extend into the septum which divides them, pass from the one to the other and are lost into each other, in several points. They are exceedingly red, short, close, and united by a cellular tissue, in which fat scarcely ever accumulates.

These fibres, forcibly pressed against each other, form a tissue similar to the fleshy part of the tongue, endowed with but little sensibility, but contractile in the highest degree. Vessels and nerves, in considerable number, if compared to the bulk of the heart, pervade this muscular tissue, whose contraction, whatever in other respects may be the direction of its fibres, tends to draw towards the centre of the cavities, every point of their parietes. Lastly, a very fine membrane lines the inner part of these cavities, facilitates the flow of the blood, and prevents the infiltration of that fluid.

LII. If we suppose, for a moment, that all the cavities of the heart are perfectly emptied of blood, and that they fill in succession, the following may be considered as the mechanism of the circulation through the heart. The blood brought back from every part of the body, and deposited into the right auricle, by the two venæ cavæ, and by the coronary vein, separates its parietes and dilates it, in every direction. The irritation attending the presence of the blood, stimulates the auricle to contraction; this fluid, which is incompressible, flows back, in part, into the veins, but it chiefly passes into the pulmonary ventricle, through a large aperture, by means of which it communicates with the right auricle. The auricle after freeing itself of the blood with which it is filled, relaxes and again dilates by the accession of a new supply of this fluid, continually brought by the veins which open into it.

However, the right ventricle, filled with the blood which it has received from the auricle, contracts in its turn on the fluid whose presence excites its parietes, and tends, in part, to return it into the right auricle, and to send it along the pulmonary artery. Regurgitation from the ventricle into the auricle, is prevented by the tricuspid valve, a membranous ring surrounding the edge of the opening of communication, and the free edge of which is divided into three divisions, to which are attached small tendons terminating into the columnæ carneæ of the heart. These valves laid against the parietes of the ventricle, the instant the blood passes into its cavity, recede from them when it contracts, and rise towards the auricular opening. They cannot be forced into the auricle, as their free and loose edge is kept in its situation by the columnæ carneæ, which are like so many little muscles whose tendons inserted into the loose edges of the valves, bind them down, when the stream of blood tends to force those membranous folds towards the auricles. The three divisions, however, of the tricuspid valve, by rising towards the auricular aperture, return into the auricle, all the blood contained in the inverted cone which they form, immediately before rising. Besides, these three portions of the tricuspid valve do not close completely the aperture, around which they are placed, they are perforated by a number of small holes: a part of the blood, therefore, returns into the auricle, but the greatest portion is sent into the pulmonary artery. The action of this vessel begins, when the parietes of the ventricle are in a state of relaxation, and the blood would be forced back into the ventricle, if the sygmoid valves, by rising suddenly, did not prevent it. Supported on a kind of floor formed by three valves which lie across the caliber of the vessel, the blood pervades the tissue of the lungs, and flows along the divisions of the pulmonary vessels; from the arteries it passes into the veins, and these, four in number, deposit it into the left auricle. This auricle, stimulated by the presence of the blood, contracts in the same manner as the right, part of the blood flows back into the lungs, but the greatest part enters the left ventricle, which sends it along the aorta, to every part of the body, whence it returns to the heart by the veins. The return of the blood into the left auricle, is prevented by the *mitral* valve which is similar to the *tricuspid*, except that its loose edge is divided only into two divisions. As soon as the blood has reached the aorta, this vessel contracts, its sygmoid valves fall, and the blood is sent to every part of the body which is supplied by some of the innumerable branches of that great artery.

In a natural state, the circulation is not carried as has been just stated; and, we have supposed this successive action of the four cavities of the heart, only to render more intelligible the mechanism of the circulation in that organ. If we lay bare the heart in a living animal, we observe, that the two auricles contract at the same time, that the contraction of the ventricles is likewise simultaneous, so that while the auricles are contracting, to expel the blood which fills them, the ventricles are dilating to receive it. This successive contraction of the auricles and ventricles is readily explained, by the alternate application of the stimulus which determines the action of these cavities. The blood which the veins bring into the auricles, does not excite their contraction, till a sufficient quantity has been collected. While this accumulation is taking place, they yield, and the resistance which is felt on touching them, during their diastole, depends, almost entirely, on the presence of the blood which separates and supports their parietes. The same applies to the ventricles; they cannot contract, until a sufficient quantity of blood is collected within them; that there remains some blood in these cavities, for they are never completely emptied, is no objection to the theory, since this small quantity is not sufficient to bring on contraction of the heart, and is not worth taking into account.

If I am asked, why the four cavities of the heart do not all contract at once, I answer, that it is easier to assign the final, than the proximate cause. If the contraction of these cavities had been simultaneous, instead of being successive, it is evident, that the auricles could not have emptied themselves into the ventricles. The alternate action is moreover absolutely necessary, as the heart any more than the other organs, is unable to keep up a perpetual action; the principle of its motion, which is soon exhausted, being incapable of restoring itself, except during rest. But, as was observed at the beginning of this work, in speaking of the vital power and functions, the alternations of action and repose in organs which, like the heart, perform functions essential to life, must be extremely short in their duration and at very close intervals.

The cavities of the heart, however, are not entirely passive during dilatation, and the action of that organ does not wholly depend on the excitement of the blood on its parietes, since the heart after it has been torn from the body of a living animal, palpitates, its cavities contract and dilate, though quite emptied of blood, and appear agitated by alternate motions, which become fainter as the part gets cold. If you attempt to check the diastole of the heart, this organ resists the hand which compresses it, and its cavities appear endowed with a power which Galen termed *pulsive;* in virtue of which they dilate to receive the blood, and not because they receive it. In that respect, the heart differs essentially from the arteries, whose dilatation is occasioned by the presence of the blood, whatever some physiologists may have said to the contrary. I have repeated, but unsuccessfully, the famous experiment by which it is attempted to be proved, that these vessels have the power of moving independently of the presence of the blood.—An artery tied and emptied of blood, contracts between the two ligatures and is no longer seen to move in alternate contractions.

LIII. The heart manifestly shortens itself, and the base approaches towards the apex, during the systole or contraction of the ventricles. If it became elongated, as some anatomists have thought, the tricuspid and mitral valves would be incapable of fulfilling the functions to which they are destined, since the columnæ carneæ, whose tendons are inserted in the edges of these valves, would keep them applied to the parietes of the ventricles. The pulsations which are felt, in the interval between the cartilages of the fifth and sixth true ribs, are occasioned by the apex of the heart which strikes against the parietes of the chest. In the explanation of this phenomenon, it is not necessary to admit the elongation of the heart during its systole; it is sufficient to consider, that the base of the heart, in which the auricles are situated, rests against the vertebral column, and that these two cavities, by dilating at the same time, and by their inability to move the vertebræ, before which they are situated, displace the heart, and thrust it downwards and forwards. This motion depends likewise, on the effort which the blood sent into the aorta makes, to bring to a straight line the curvature of that artery, which reacts and carries downwards and forwards the whole mass of the heart, as it were, suspended to it.

The quantity of blood which each contraction of the ventricles sends into the aorta and pulmonary artery, most probably, does not exceed two ounces in each of these vessels. The force with which the heart acts on the blood which it sends into them, is but imperfectly known, however numerous the calculations by which it has been endeavoured to solve this physiological problem. In fact, from Keil, who estimates at a few ounces only, the force of the heart, to Borelli, who makes it amount to one hundred and eighty thousand pounds, we have the calculations of Michelot, Jurine, Robinson, Morgan, Hales, Sauvages, Cheselden, &c.; but as Vicq-d'Azir observes, not one of these calculations is without some error, either anatomical or arithmetical: hence we may conclude with Haller, that the force of the heart is great, but that it is perhaps impossible to estimate it with mathematical precision. If we open the chest of a living animal, and make a puncture in his heart, and introduce a finger into the wound, pretty considerable pressure is felt, during the contraction of the ventricles.

Those who admit, to its full extent, Harvey's opinion on the circulation of the blood, and who think with him, that the heart is the sole agent of the circulation, over-rate the power of that organ, so as to proportion it to the extent of the course which the blood is to take, and to the number of the obstacles which it is to meet in its way. But, as I am about to state, the blood vessels should not be considered as inert tubes, in which the blood flows from the mere impulse which it has received from the heart.

LIV. *Of the action of the arteries.* There is no part of the body to which the heart does not send blood by the arteries, for, it is impossible to make a puncture, with the finest needle, into any of our organs, without wounding several of these vessels and causing an effusion of blood. The aortic arterial system may be compared to a tree, whose trunk, represented by the aorta, having its root in the left ventricle of the heart, extends afar its branches, and throws out, on every side, its numerous ramifications. The size of the arteries decreases, the farther they are from the trunk by which they are given off. Their form, however, is not that of a cone, they are rather cylinders arising from one another, and decreasing successively in size. As the branches given off by a trunk, taken collectively, have a greater diameter than that of the trunk itself, the capacity of the arterial system increases with the distance from the heart, hence it follows, that as the blood is continually flowing from a straiter to a wider channel, its course must slacken. The direction of the arteries is often tortuous, and it is observed, that the arteries which are sent to hollow viscera, as the stomach, the uterus and the bladder, or other parts capable of contracting, of stretching, and of changing their dimensions every moment, as the lips, are much the most curved, no doubt, that they may by unfolding, give way to the extension of the tissues into which they are distributed. Lastly, the arteries arise from one another, and form with the trunk or branch from which they are given off, an angle varying in size, but which is always obtuse, and more or less acute towards the branch.

As the arteries recede from their origin, they communicate together, and these anastomoses form arches, two branches bending towards each other, and joining at their extremities, as we see in the vessels of the mesentery; sometimes two parallel branches meet at an acute angle, and unite into one trunk, thus the two vertebrals join to form the basilary artery; some communicate by transverse branches which pass from the one to the other, as is seen within the skull.

In the anastomoses of the first kind, the columns of blood flowing, in contrary directions, along the two branches, meet at the point of union, and mutually repel each other, their particles mingle, and lose much of their motion in that reciprocal shock. The blood then follows a middle direction, and enters the branches which arise from the convexity of these anastomotic arches.

When two branches unite to produce a new artery, of a greater caliber than each taken separately, but not so large as both together, the motion of the blood becomes accelerated, because it passes from a more capacious into a straiter channel, and the forces which determined its progression, are concentrated into one. Lastly, the transverse anastomoses are well calculated to promote the passage of the blood from the one branch into the other, and to prevent congestion in the parts.

LV. The arteries are imbedded in a certain quantity of cellular tissue, are almost universally accompanied by corresponding veins, by lymphatics and nerves, and their coats are thicker in proportion as their caliber is smaller. The experiments of Clifton Whittringham prove, that the parietes are stronger in the small than in the large arteries, hence it is observed, that aneurisms are much less frequent in the former. Their parietes have sufficient firmness not to collapse, when the tube of the artery is empty. They are formed of three coats; the external or cellular admits of considerable extension, and appears to be formed by the condensation of the laminæ of the cellular tisssue which surrounds the artery and unites it to the neighbouring parts. The second coat is thicker and firmer, of a yellow colour, and fibrous, and is by some considered as muscular[*] and contractile, while other physiologists merely allow it to possess a considerable degree of elasticity. The longitudinal fibres, admitted by some authors in the texture of this second coat, cannot be distinguished, and their existence is not necessary to account for the longitudinal retraction of arteries. In fact, this retraction might depend on elasticity, it might likewise be occasioned by the contraction of fibres not absolutely circular nor longitudinal, but spiral and imperfectly surrounding the vessel, and crossing each other, in various directions. This yellow coat, thicker in proportion, in the smaller arterial twigs, than in the larger branches, and thicker in these than in the trunks, is dry, hard, not capable of much extension, and is ruptured by an effort to which the external coat yields by stretching. Lastly, a third, thin, and epidermoid coat lines the inside of these vessels, and seems less calculated to give strength to the parietes of the arteries, than to facilitate the flow of the blood, by presenting to it a smooth, even, and slippery surface, continually moistened by a serous exudation, from the minute arteries, or vasa vasorum which are distributed between these coats.

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[*] If in man and the greater number of animals, the yellow fibres which form this coat, differ greatly from muscular fibres, they in the elephant resemble that texture very completely, as I had an opportunity of observing, when I witnessed the dissection of the elephant that died in the year X. at the Museum of Natural History. Let men of judgment decide, whether the analogy is sufficient to warrant our admitting, in the arteries of the human body, the existence of muscular fibres.

Besides these three coats, the great arteries receive a fourth from the membranes lining the great cavities; thus, the pericardium and the pleura in the chest, the peritoneum in the abdomen, furnish to the different parts of the aorta, an adventitious coat which does not completely surround the vessel.

Of the three coats which form the parietes of the arteries, the fibrous, though thicker than the other two, offers, however, the least resistance. If you take the carotid artery which, for a considerable space, does not send off any branches, and forcibly inject into it a fluid, the internal and middle coat will be torn, before dilatation has increased, by one half, the caliber of the vessel. The external coat resists the cause of rupture by dilating, and forms a tumour, and it is only by applying a pretty considerable force, that it can be ruptured. The experiment is attended with the same success, if performed with air or any other gas. In aneurism, the internal and fibrous coats of the arteries, but more particularly the fibrous are ruptured at an early stage of the disease, which at that period increases suddenly, in a very rapid manner, and on opening the tumour, it is observed, that the sac is entirely formed by the dilated cellular coat. Take an artery of a certain caliber, for example, the carotid or humeral, apply a ligature around it and tighten it with some degree of force. Dissect and take out the vessel, then cut the thread, and examine the place to which it was applied, you will observe, that the parietes of the artery, are in that part thinner, and formed merely by the cellular coat which alone has withstood the constriction. Take hold of the two ends of an insulated arterial tube and stretch it, then examine its inner coat, and you will find it torn and cracked in several places, and the parietes of the artery evidently weakened.

LVI. This want of extensibility in the coats of arteries, is the principal cause of aneurism; hence the popliteal artery is so liable to that affection, from its situation behind the knee, whose extension is limited, merely by the resistance of the posterior tendons and ligaments; this artery is affected by the jar which takes place through all the soft parts, when the leg is violently extended; and being less extensible than the other parts, its inner coat is ruptured, or at least weakened, so as to occasion an aneurism, always rapid in its progress. Of ten popliteal aneurisms which I have seen in different hospitals, eight were ascribed to a violent extension of the ham. In looking over the cases that have been recorded, it will be seen, that a considerable number of aneurisms of the aorta, have been occasioned by too forcible and too sudden an extension of the trunk in raising a heavy burthen.

From the dryness, the frailty of the yellow or fibrous coat of arteries, the application of ligatures to these vessels is attended with a speedy laceration of their tissue; a moderate degree of compression is sufficient to rupture that coat, the external and internal remaining, at the same time, uninjured provided the constriction be not excessive. Why is the arterial tissue, almost the only one on which ligatures require to be applied, the least fitted of all the organic tissues to bear them? This inconvenience attending the ligature of arteries, led Pouteau to prefer tying arteries so as to include the surrounding soft parts within the ligature, though this process is, in other respects, less eligible. The objections will be obviated, by employing flat ligatures, which, by acting on a greater surface of the artery, are less likely to divide the coats of the vessel which will become obliterated at the spot to which the ligature is applied, the more rapidly as the patient is younger and stronger.

I once saw, in a man whose thigh was amputated, on account of caries of the knee joint combined with a scorbutic affection, hemorrhage attend the fall of the ligatures, which did not come away till nineteen days after the operation; as if the fibrous coat of these arteries, partaking in the debility of the muscular organs, had not preserved a sufficient degree of contractile power to close the cavity of the vessel.

LVII. The contractile power of the arteries is in their middle coat, it is greater, as this coat is thicker in proportion to the caliber of the artery. Hence, as Hunter observes in his work on the blood and inflammation, the larger arteries are endowed with elasticity, merely, while on the other hand, contractility is very apparent in those of a smaller caliber, and is found complete in the capillary vessels: hence, in the trunks near the heart, the progression of the blood is effected, chiefly by the impulse which it receives from the heart, and as Lazarus Riviere observed, the circulation of the blood in the large vessels, is more an hydraulic than a vital phenomenon. The action of the main arterial trunks, near the heart, has so little influence on the motion of the blood sent into them by that organ, that the aorta is frequently ossified, without affecting the circulation. The aorta is naturally bony in the sturgeon. J. L. Petit, in the case of a bookseller whose leg he had taken off, found all the arteries of a certain caliber, in a state of ossification, they were indurated, and, of course, incapable of acting, in the slightest degree, on the column of blood which flowed along them. All these facts seem conclusive arguments in favour of those physiologists, who explain, on the principle of elasticity, the contraction of arteries. But however correct this explanation may be, with regard to the vessels near the heart, it does not apply to the capillaries; the influence of that organ does not operate on these vessels. One may easily conceive, that the column of blood which by the impulse it has received, in the first instance, has been sent along the whole length of tubes whose sides are ossified, inflexible, and consequently inert, on reaching the extremity of these canals, is, in a manner, again taken up by the vital power residing in the capillary vessels, and circulates from the influence of the action belonging to these vessels. Besides, elasticity, however considerable, merely restores those tissues that have been stretched, to the condition in which they were before extension.—Elasticity is a kind of re-action, proportionate or relative to the action which precedes it. Why do arteries in the living body contract, to such a degree, that when empty, their canal becomes obliterated, while in the dead body, however perfect the depletion of the arterial system may have been, the cavity of the arteries remains perfectly open. Several physiologists, however, and those among the most modern, consider elasticity as the principal cause of the progression of the blood along the arteries.

As the distance from the centre increases, the circulation slackens, from several causes, and the blood could not reach all the parts of the body, if the arteries, whose vitality increases with their distance from the heart, and as they become smaller, did not propel it to all the organs. The causes which retard the circulation of the arterial blood, are, the increased dimensions of the space in which it is contained;—the resistance from the curves of the vessels ;—the friction which it undergoes, and which increases, as, at a distance from the heart, the canals along which it circulates, increase in number; and lastly, the deviations which the blood meets with in its course, from the trunks into the branches, which, coming off sometimes, almost at right angles, divert it from its original direction.

Several physiologists have called in question, this progressive slackening of the flow of arterial blood, and several among them, who reject entirely the application of the physical sciences to that of the animal economy, have, nevertheless, supported their opinion by a fact taken from hydraulics. To give any certainty to these calculations, respecting the impediments to the circulation of the blood in the arteries, it would, they say, be necessary, that the arteries should be empty at the instant when they receive the jet of blood sent into them by the contraction of the ventricles. This, however, is not the case ; the arteries are always full, the blood flows along all of them with the same degree of velocity. This system of vessels may be compared to a syringe, from which a number of straight and tortuous tubes should arise ; each of these would throw out the fluid with an equal degree of velocity, on applying pressure to the piston.

In refuting this doctrine, I must take notice of the manifest contradiction of pretending to exclude, absolutely, all application of the principles of mechanics to physiology, and the complete application of these principles to the phenomena of the animal economy. This contradiction, however, is not more surprising than that of authors who exclaim against the abuse of modern nomenclatures, and who, nevertheless, eagerly embrace every opportunity of adding to it, by assigning new names to such parts as may have escaped the attention of the new nomenclators. What resemblance is there, between a forcing pump, whose sides are unyielding, as well as those of the tubes which might arise from it, and the aorta which dilates every time the blood is sent into it ; and again, what resemblance is there, between tubes which decrease towards their open extremities, while the space contained in the arterial tube constantly enlarges, from the innumerable divisions of the vessels. Since it is admitted, that the course of the blood is slower in the capillary vessels, must not this resistance, opposed to the blood which fills the series of vessels from the capillaries to the heart, be felt more at a greater distance from that organ, &c.? Without this progressive increase of resistance, as the arterial blood is at a greater distance from the heart, this fluid would flow along the arteries, as it does along the veins without any pulsations; for, this resistance, which causes the lateral effort of dilatation effected by the blood on the parietes of the arteries, is the principal cause of the pulse, which belongs only to that set of vessels. A very remarkable difference is observable, between the blood which is sent to the toes, and that which goes to the mammæ, as I have several times noticed in removing the carious bones of the toes, or in extirpating cancerous breasts; the small arteries of these parts are nearly of the same size, but the jet of blood is much more rapid, the blood is sent to a much greater distance, when one of the mammary arteries is divided.

The re-action of the arteries on the blood which dilates them, depends not only on the great elasticity of their parietes, but likewise on the contractility of the muscular coat. Elasticity has a considerable share in the action of the larger trunks, while contractility is almost the sole agent, in producing the action of the minute arteries. If a finger is introduced into the artery of a living animal, its parietes compress it in every direction; if the blood is prevented from flowing in it, the canal becomes obliterated by the adhesion of its parietes, and the vessel is converted into a ligamentous cord, such as that formed in the adult, by the remains of the umbilical arteries and veins. This contractility which, during life, is always in action, keeps the arteries, distended by the blood which fills them, of a smaller caliber, than after death. In performing capital operations, especially in the amputation of limbs, I have always found the arteries, whether filled with blood or empty, much smaller than I should have expected from their appearance in the dead body.

It happens, however, sometimes, that the quantity of blood sent to an organ increases, in consequence of some cause of irritation; the caliber of the arteries of the part, then becomes remarkably enlarged. Thus, the arteries of the uterus, which are very small in its unimpregnated state, acquire, towards the end of pregnancy, a caliber equal to that of the radial artery: the small arteries which are sent to the mammæ, are not in the same condition, as I have had an opportunity of ascertaining in a woman who had been suckling a child for two months before her death; they retained their almost capillary minuteness, which would seem to prove, that the lymphatics are alone concerned in bringing to these glands the materials of their secretion. The mammary arteries are evidently enlarged in open cancer of the breast; in cancer of the penis, the blood vessels likewise become enlarged; hence in removing the penis for that affection, it is absolutely necessary to secure the arteries with ligatures, a precaution which need not be attended to, in a case of gangrene. Gangrene is attended with this peculiarity, that the arteries of the mortified parts contract, so as to become obliterated, when their caliber is inconsiderable.

As the arteries are the canals which convey to all our organs the materials of growth and reparation, they are larger, in proportion, in children, in whom nutrition is more active, and their caliber is always proportionate to the natural or morbid developement of organs: hence the descending aorta and the iliac arteries are larger in women than in men; hence the right subclavian artery, which conveys blood to the larger and more powerful of the two upper extremities, because the more employed, is larger than the left subclavian. But the effect should not be mistaken for the cause, and it should not be imagined, that the right upper extremity owes its superiority to the greater caliber of its artery. In the new born child, this vessel is not larger than the left subclavian; but the right arm being more frequently employed, the distribution of the fluids takes place more favourably, nutrition is carried on with more energy, it acquires more bulk and strength, and therefore the right subclavian artery conveys blood to it by a wider channel. If the left upper extremity were employed in the same manner, and if the right were kept in a state of inaction, the left subclavian would, no doubt, exceed the right. I am warranted by two facts, in forming this conjecture. In dissecting the bodies of two men that were left-handed, I observed in the left subclavian arteries, the same proportionate enlargement which is usually met with in the same vessels on the right side.

LVIII. As the arteries are always full during life, and as the blood flows along them with less velocity, the greater their distance from the heart, the blood which the contractions of the left ventricle send into the aorta, meeting the column of blood already in that vessel, communicates to it the impulse which it has received; but retarded in its direct progression, by the resistance of that column, it acts against the parietes of the vessels, and removes them to a greater distance from their axis. This lateral action which dilates the arteries, depends, therefore, on the resistance of the parietes of these cavities, always filled with blood, to that which the heart sends into them. This dilatation, which is more considerable in the large arteries than in the smaller ones, manifests itself by a beat, known under the name of *pulse.* The experiments of Lamure would lead one to believe, that another cause of this phenomenon is a slight displacement of the arteries, every time they dilate. These displacements are most easily observed at their curvatures, and where they adhere to surrounding parts, by a loose and yielding cellular tissue.

The pulse is more frequent in women, in children, in persons of small stature, during the influence of the passions, and under violent bodily exercise, than in an adult man, of high stature, and of a calm, physical and moral nature. At an early period of life, the pulse beats as often as a hundred and forty times in a minute. But as the child gets older, the motion of the circulation slackens, and at two years old, the pulse beats only a hundred times, in the same space of time. At the age of puberty, the beats of the pulse are about eighty in a minute; in manhood, seventy five, and lastly, in old men of sixty, the pulse is not above sixty. It is slower in the inhabitants of cold, than in those of warm climates.

Since the time of Galen, the pulse has furnished physicians with one of their principal sources of diagnosis. The force, the regularity, the equality of its pulsations, opposed to their weakness, inequality, irregularity, and intermittence, afford the means of judging of the nature and danger of a disease, of the power of nature in bringing about a cure, of the organ that is most affected, of the time or period of the complaint, &c. No one has been more successful than Bordeu, in the consideration of the pulse, under these different points of view. Its modifications indicative of the periods of diseases, establish, according to that celebrated physician, as may be seen in his *Recherches sur le pouls par rapport aux crises,* the pulse of *crudity,* of *irritation,* and of *concoction.* Certain general characters indicate, whether the affection is situated above or below the diaphragm, hence the distinction of *superior and inferior pulse.* Lastly, peculiar characters denote the lesion of peculiar organs; which constitutes the nasal, guttural, pectoral, stomachic, hepatic, intestinal, renal, uterine, &c.

Besides these sensible beats, which constitute the phenomenon of the pulse in the arteries, there is an inward and obscure pulsatory motion, by which all the parts of the body are agitated, every time that the ventricles of the heart contract. There is a kind of antagonism between the heart and the other organs, they yield to the impulse which it gives to the blood, dilate on receiving this fluid, and collapse when the effort of contraction is over. Every part vibrates, trembles, and palpitates within the body, the motions of the heart shake its whole mass, and these quiverings, which may be observed externally, are most manifest when the circulation is carried on with rapidity and force. In some head aches, the internal carotid arteries pulsate with such violence, that not only the ear is sensible to the noise made by the column of blood striking against the curvature of the osseous canal, but the head is evidently moved and raised, as it were, at each pulsation. If you look at your hand or foot, when the upper or lower extremity is quiescent and pendulous, you will observe in it, a slight motion corresponding to the beats of the heart. This motion increases, and even makes the hand shake, when, from the influence of the passions, or from violent exercise, the circulation is accelerated; in every violent emotion, we feel, within ourselves, the effort by which the blood, at each beat of the pulse, penetrates into our organs and fills every tissue. And it is, in a great measure, from this inward tact, that we are conscious of existence. A consciousness the more lively and distinct, as the effect of which we are speaking, is more marked. It is, likewise, from observing this phenomenon, that several physiologists have been led to conceive the idea of a double motion, which dilates or condenses, which contracts or expands, alternately, all organs endowed with life; they have observed, that dilatation prevails in youth, in inflammation and erection, conditions of which all parts are capable, according to their difference of structure.

LIX. At the moment when the left ventricle contracts, to send the blood into the aorta, the sigmoid valves of that artery rise, and apply themselves to its parietes, without, nevertheless, closing the orifices of the coronary arteries, which lie above the loose edges of the valves; so that the blood is received into these vessels, at the same time as into the others. When the contraction of the ventricle is over, the aorta acts on the blood which it contains, and would send it back into the ventricle, if the valves, by suddenly descending, did not present an insuperable obstacle to the return of the blood, and did not yield a point of resistance to the action of the whole arterial system; only the small quantity of blood below the valves, at the moment of their descending, flows back towards the heart, and returns into the ventricle.

Though the rate at which the blood flows along the aorta, has been estimated at only about eight inches in a second, a pulsation is felt in all the arteries of a certain caliber, at the instant the ventricles are contracting. The reason that the pulsations of the heart appear to take place, at the same time as those of the arteries, is, that the columns of blood, in these vessels, receive an impulse from that which is issuing from the ventricles, and this concussion is felt in an instant of time, too short to be measured, such as that which is felt by the hand applied to the end of a piece of timber struck, at the other end, with a hammer. The blood which fills a main trunk, supplies to each of the branches which arise from it, columns proportionate to their caliber. This division of the principal column is effected, by a kind of projection at the mouth of each artery. These internal projections detach from the main stream, the lesser ones, and these flow the more readily into the branches, according as these arise from the trunk, at a more acute angle, as the projection is more prominent and the deviation of the fluid less considerable. If the branches are given off, at an almost right angle, the orifices of the arteries scarcely project at all, and nothing but the effort of lateral pressure determines the flow of the blood into them.

The flow of the blood into the arteries which are distributed to muscles, is not interrupted, when these muscles contract, for, whenever arteries, of a certain caliber, penetrate into muscles, they are surrounded by a tendinous ring, which, during the contraction of the muscle, becomes enlarged, from the extension in every direction, effected by the fibres which are attached to it, around its circumference. The existence of this truly admirable conformation, may be readily ascertained, by observing the aorta, in its passage through the crura of the diaphragm; the perforating arteries of the thigh, where they enter at the back part of the limb into the adductor muscles, the popliteal, as it passes through the upper extremity of the soleus muscle.

LX. *Of the capillary vessels.* The arteries, after dividing into branches, these branches into lesser ones, and these into progressively smaller ramifications, terminate in the tissue of our organs, by becoming continuous with the veins. The venous system arises, therefore, from the arterial system, the origins of the veins being merely the more minute extremities of the arteries, which becoming *capillary* from the great number of divisions* they have undergone, bend in an opposite direction and become altered in their structure.

These minute capillary arteries form with the minute veins, with which they are continuous, and with the lymphatics, wonderful meshes in the tissue of our organs.

Several physiologists consider the capillary blood vessels, as an intermediate system between the arteries and veins, in which the blood, entirely out of the influence of the action of the heart, flows slowly, with an oscillatory and sometimes retrograde motion, is no longer red, because its globules are strained, as it were, and, in a manner, lost in a colourless serum, which serves them as a vehicle.

It is, in fact, necessary, that bodies should be of a certain bulk, to reflect the rays of light at an angle sufficiently obtuse, that the eye may discover their colour. We know, that grains of sand reduced to a very fine dust, appear colourless, when examined separately, and are seen to possess colour, only when in a state of aggregation: further, very thin laminæ of a horny substance, appear transparent, though the part from which they have been detached, be of a red or blue colour. But if several of these transparent laminæ be laid on one another, the red colour becomes darker, in proportion as a greater number are brought together.

Let irritation, from whatever cause, determine the blood to flow into the serous capillary vessels, in greater quantity, and with more force, these vessels will become apparent, the organs in whose structure they circulate, will acquire a red colour, more or less deep; thus the conjunctiva, the pleura, the peritoneum, the cartilages, the ligaments, &c. which, naturally, are whitish or transparent, become red, when affected with inflammation, whether from the increased impetus of the circulation, which forces and accumulates into the capillary vessels, a greater number of red globules, or that the sensibility of these small vessels is impaired by inflammation, so that they admit globules which they formerly rejected.

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[*] The arterial divisions which may be discerned by the aid of anatomy, do not exceed eighteen or twenty; nevertheless, they divide still further, when they are become so minute as not to be discernible with the help of the most powerful microscope.

Some capillary vesssels transmit blood, at all times, and uniformly exhibit a red colour; this is the case with the capillary vessels of the spleen, of the corpora cavernosa of the penis, of the bulb and corpus spungiosum of the urethra; the same applies to the capillaries of the muscles, of the mucous membranes, there are, however, very few of those organs, in which the whole portion of the capillary tube, between the termination of the artery and the origin of the vein, is filled with red blood. There is, almost always, a division in the tortuous line described by the capillary, and within this space, the blood cannot be detected of its usual colour.

The number of the capillary vessels, as well as that of the arteries, to which the former are as auxiliaries, is much more considerable in the secretory organs, than in those in which life carries on only the process of nutrition. It is on that account, that the bones, the tendons, the ligaments, the cartilages, contain so much smaller a quantity of blood, than the mucous and serous membranes, and the skin. The capillary vessels are, however, very numerous, in the muscles, which owe that colour to the great quantity of blood they contain, but as we shall point out, when we come to speak of motion, this fluid appears to form an essential element in muscular contraction; it is, therefore, not to be wondered, that these organs should have a greater number of capillary vessels sent to them: since these vessels do not supply them merely with molecules to carry on nutrition and to repair the waste of the part, but impart to them the principle of their frequent contraction: the quantity of them is so considerable, in all these parts, employed in the two fold offices of nutrition and secretion, that Ruysch penetrated, with his injections, the whole thickness of their substance, to such a degree, that the organs which he had prepared, were only a wonderful and inextricable network of capillary vessels extremely minute. On these anatomical preparations, made with an art hitherto unrivalled, Ruysch grounded his hypothesis relative to the intimate structure of the body, in which, he imagined, all was capillary tubes, a hypothesis which has obtained the most favourable reception, and has reigned, during more than a century, in the schools. It is enough to reflect a moment on their uses, to conceive that the number of them must be really prodigious. As long as the blood is enclosed within the arteries, and flows under the controul of the heart, it fulfills no purpose either of nutrition or secretion. To make it subservient to these great functions, it must be diffused through the very tissue of the organs, by means of the capillary divisions; these little vessels exist then, in every part, where any organized molecules are found united; since the particle formed by their assemblage, must, at least, find, in the juices which they bring to it, the materials of its reparation. Entering, in greater or less proportion, into the organization of all the tissues, the capillaries receive certain modifications from the organs of which they are an integral part: modifications which enable them to deposit the serous part of the blood on the surface of the serous membranes, admit the transudation of the fat into the cells of the cellular tissue, furnish the urine to the kidneys, and the liver with the materials of the bile: in a word, suffer to escape, through the porosities with which their parietes are pierced, the principles which the blood has to furnish to every organ.

It is by these lateral porosities, and not by extremities open on all the surfaces, and in all the points of the organs, that the capillaries transpire, in some sort, the elements of nutrition, and of the various secretions. Mascagni was aware, that Nature, skilful in deducing many effects from few causes, has not deviated, in the construction of the system of circulation, from the invariable laws of her ordinary simplicity: but the lateral pores of the capillaries, which are sufficient for the explanation of all the phenomena ascribed to the exhaling mouths of the arteries, and to the pretended continuity of these vessels with the excretory ducts of the organs, &c. are not openings like the pores common to all matter; each of them may be considered as an orifice, sensible, and, especially, contractile, of differing size, according to the state of the strength or of the vital powers. The size then of these capillary pores is subject to frequent variations; and this is the explanation given of the formation of scorbutic ecchymoses, of petechiæ, of passive or relaxed hemorrhages. In all these affections, contractility being really diminished, the pores of the capillaries enlarge, and suffer the red blood to transude through their relaxed mouths. This phenomenon takes place, not only under the skin and on the various mucous surfaces, it is observed also in the very tissue of the organs. It is thus, that I have often seen, on opening the bodies of those that had died of scurvy, in its last stage, the muscles of the leg filled with blood. This sort of interior hemorrhage, converts the muscles into a kind of pulp; and the extravased blood itself undergoes a beginning of decomposition.

The bones themselves are liable to these scorbutic bloody infiltrations. I had an opportunity of ascertaining this in the Hospital of St. Louis, at the same time that I learnt the difficulty of procuring a durable skeleton from such bodies. The greatest number die, in a very advanced stage of the disease, and the bones dissolve in maceration, or rot in a very little time.

The capillary vessels, whether the blood flow through them red, or colourless, are not a system of vessels distinct from that of the arteries, and from that of the veins; they belong essentially to these two orders of vessels. Those which, ramifying in the tissue of the skin, or of the serous membranes, suffer the serum of the blood to transude, are not more entitled to the name of exhalant system, which some authors have given them. To consider as distinct and insulated systems, separate parts of a system of organs, is to encumber science with a crowd of divisions, as false as they are useless.

LXI. The sanguineous capillaries anastomose, and form, like the lymphatic capillaries, a net-work that envelopes all the organs. Their frequent communications do not allow obstructions to take place and to produce inflammation, as Boerhave thought, and as was long taught, on the authority of that celebrated physician. Haller, Spallanzani, all the microscopic observers, have perceived threads of blood flowing in the capillaries, offering themselves at the various inosculations of these vessels, and have seen them flow back, when they were not admitted, to seek other easier entrances.

I will not heap up, in this place, superfluous arguments against the theory of the Leyden professor, rejected at its birth by the physicians of Montpellier, absolutely refuted, and now universally given up. Irritation alone keeps the blood in the inflamed part; for, when death, which puts an end to all irritations, and relaxes all spasms, (*mors spasmos, solvit.* Hipp.) When I say, death comes on, all slight inflammations are dissipated, and whenever they have not been sufficiently intense, to induce transudation of the blood through the parietes of the capillaries, into the *areolæ* of the organic tissues, the blood flows back into the large vessels, and there is no trace of it left. It is thus, that erysipelas of the skin disappears, that the pleura preserves its transparency, in individuals affected, before death, with sharp pains in the side. If to this, we add our ignorance on the real organization of the nervous system, on the conditions absolutely required of the brain and nerves, for the maintenance of life, we shall cease to be surprized, that the opening of bodies has taught us no more on the real seat of disease, and we shall confess with Morgagni, who however employed, with great success, this means of improving the art of healing, that there are numberless diseases, of which, after death, no trace is left, and for the fatal termination of which, we are unable to account.

Contractility and sensibility exist, in a much higher degree, in the capillary and serous vessels, than in the veins and arteries. Life must needs be more active in the former, for, the motion given to the blood by the contractions of the heart, being exhausted, this fluid, no longer in the sphere of action of that organ, can circulate, but from the influence of the action of the vessels themselves.

The termination of the arteries into veins, is the only well ascertained termination of those vessels; it may be seen by the help of the microscope, in cold-blooded animals, in frogs and salamanders. In some fish, we may, even with the naked eye, observe frequent and considerable inosculations, between the arteries and veins. In man, however, and in other warm-blooded animals, these communications take place, only at the extremities of the two systems of vessels. In this case, the arteries terminate, sometimes, in capillary vessels carrying serous fluid, such are the vessels of the sclerotic coat; these vessels become small veins whose caliber gradually increases, until they admit red globules in sufficient number to reflect that colour. At other times, the artery and vein are continuous, without the intervention of that extremely minute subdivision; the red blood then passes readily and immediately from the artery into the vein.

It will be shewn, in speaking of secretions, that the continuation of the arteries into the excretory ducts of the conglomerate glands, and their termination in exhaling orifices, cannot be admitted, and that the presence of small pores, in the sides of the minute arteries and veins, would afford an explanation of the phenomena on which the belief of this termination of the arteries rests. There exists no parenchyma, no spungy tissue, between the extremities of the arteries and the origin of the veins, with, perhaps, the exception of the substance of the cavernous bodies of the penis and of the clitoris, of the bulb and spungy part of the urethra, the retiform plexus, which surrounds the orifice of the vagina, and perhaps also the tissue of the spleen, though the experiments of anatomists (Mascagni and Lobstein) seem to prove, that in these organs, the arteries and veins are immediately continuous.

LXII. *Of the action of the veins.* These vessels, whose function it is to carry back to the heart, the blood which the arteries have sent to all the organs, are much more numerous than the arteries themselves. It is observed, in fact, that arteries of a middle size, as those of the leg and fore-arm, have each two corresponding veins, whose caliber, at least equals theirs, and that there is besides, a set of superficial veins, lying between the skin which covers the limbs and the aponeuroses which envelop the muscles; these have no corresponding arteries. The space which the venous blood occupies is, therefore, much greater than that taken up by the blood in the arteries. Hence also, it is estimated, that of twenty-eight or thirty pounds of this fluid, making about a fifth part of the whole weight of the body in an adult man, nine parts are present in the veins, and only four in the arteries. In this calculation, one should consider as arterial, the blood contained in the pulmonary veins and in the left cavities of the heart, while that which fills the cavities in the right side of the heartand the pulmonary artery, is truly venous, and has every character of such blood.

Although the veins generally accompany the arteries, and are united to them, by a common sheath of cellular membrane, this disposition of parts is not without exceptions. The veins which bring back the blood from the liver, do not, in any respect, follow the course of the branches of the hepatic artery; the sinuses of the brain are very different, in their arrangement, from the cerebral arteries; the veins of the bones, which are particularly numerous, and of a much greater caliber than the arteries of the same parts, from the slow circulation of the blood along them, do not generally follow the direction of the arteries, and arise singly from the substance of the bone, with the exception of those in the middle canal, and which pass through the nutritious foramen of the bone. The veins are not only more numerous than the arteries, but they are likewise more capacious, and dilate more readily, this structure was necessary, on account of the slowness with which the blood circulates, and of the readiness with which it stagnates, when the slightest obstacle impedes its circulation.* The force which carries on the circulation of the blood, along the arteries, is so great, that Nature seems not to have availed herself of the mechanical advantages which might have facilitated its flow. On the other hand, the power which determines the progression of the venous blood is so feeble, that she has sedulously removed every obstacle which might have impeded its course. And as the relation of the minute to the larger branches, of these to the trunk, is the same as in the arteries, two branches unite to form a vein of greater caliber than each separate vessel, but smaller than the two taken together, the blood flows along a space which becomes narrower, the nearer it approaches the heart; the rapidity of its course, must, therefore, be progressively increased.

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* The arteries contain, at all times, nearly the same quantity of blood. The veins are always the seat of plethora, because the blood stagnates in them more readily; and this condition brings on inflammatory fever (consisting merely in

The veins are almost straight in their course; at least, they are much less tortuous than the arteries. The force which makes the blood flow along them, is consequently not taken up in straigtening these curves; the anastomoses are, likewise, more frequent, and, as the flow of the blood might have been intercepted in the deep seated veins of the limbs, when the muscles, among which these vessels lie, during contraction, compress them by their enlargement and induration, they communicate freely with the superficial veins, towards which the blood is carried, and flows the more readily, as they are not liable to be compressed. It is observed, and is to be accounted for on the same principle, that the superficial veins are very large and distinct among the lower orders who are employed in laborious occupations, requiring an almost continual exertion of their limbs. Lastly, the internal part of the veins, like that of the lymphatics, is furnished with valvular folds, formed by the duplicature of their epidermoid coat. These valves, which are seldom single, and almost always in pairs, are not found in the minute veins, nor in the great trunks, nor in the veins which bring back the blood from the viscera in the great cavities.

These valves, in falling, close completely the canal of the vessel, destroy the continuity of the column of blood returning to the heart, divide it into smaller columns, as numerous as the intervals between the valves, and the height of which is determined by the distance between these folds. So that the power which carries onward the venous blood, and which would be incapable of propelling the whole mass, acts advantageously on each of the small portions into which it is divided.

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an increased action of the vascular system, as is expressed by the term *angeioteniquc* applied to it by Professor *Pinel*) only when the venous congestion becoming excessive, the blood passes with difficulty from the arteries into the veins. The heart and the arteries then struggle, with considerable effort, to rid themselves of the fluid which oppresses them, &c.

LXIII. It has been thought, that the principal cause which makes the blood flow into the veins, is the combined action of the heart and arteries; but the impulse from those organs, is lost in the system of capilary vessels, and does not extend to the veins. The specific action of their own parietes, aided by auxiliary means, such as the motion of the neighbouring arteries, is sufficient to carry the blood on to the heart.

These parietes, which are much thinner than those of the arteries, are contained, like theirs, in a sheath common to all the vessels. Three coats, likewise, enter into their structure; the middle or fibrous coat is not very distinct, and consists merely of a few longitudinal reddish fibres, which can be distinguished only in the larger veins, near the heart. In some of the larger quadrupeds, as in the ox, these fibres form distinct fasciculi, and their muscularity is much more manifest.

The internal coat, which is more extensible than that of the arteries and equally thin, adheres more closely to the other coats. The cellular coat, which connects it to the middle one, is less abundant, hence phosphate of lime is seldom deposited into it, as happens to the arteries which frequently become ossified, as we advance in years. This internal coat is merely a continuation of that which lines the cavities of the heart; and as the origin of the inner coat of the arteries is the same, there exists a non-interrupted continuity in the membrane which lines all the canals of the circulation. The inner coat forms the only essential part of the venous system; it alone constitutes the veins within the bones, the sinuses of the dura mater, the hepatic veins, in a word, all the veins which are so firmly attached externally to the neighbouring parts, that the blood flows along them, as along inert tubes, their parietes being, almost completely, incapable of contracting.

The veins, in their passage through muscles, are, like the arteries, guarded by aponeurotic rings, than which none is more remarkable than that which belongs to the aperture in the diaphragm, which transmits the ascending cava from the abdomen into the thorax. This vessel is, therefore, not compressed by the contraction of that muscle in inspiration.

LXIV. As the inferior cava passes through the lower edge of the liver, whether along a deep fissure, or in a real canal in the parenchymatous substance of that viscus, the course of the blood must be impeded, when, from congestion of the parenchyma, the vessel is, in some sort, strangulated.

Obstruction of the liver, which is of such frequent occurrence, would have been attended with fatal consequences, by preventing the return of the blood from the inferior parts, along the ascending cava, if this great venous trunk did not keep up, by means of the vena azygos, an open and free communication with the descending or superior cava. The use of this anastomosis of the two great veins is, evidently, to facilitate the passage of the blood from the one of these vessels into the other, when either, especially the lower, does not readily evacuate its contents into the right auricle. On this account, the vena azygos is capable of considerable dilatation, and is entirely without valves. In the body of man opened, this day, in my presence, and whose liver was twice as large as in health, I observed, that the vena azygos, which was distended with blood, was of the size of the little finger; the termination downward of this vessel, in the right renal vein, and above in the superior cava, were most distinct, and by compressing it from above downward, or from below upward, the blood flowed into the one or other of these vessels.

As the causes which determine the circulation of the venous blood, communicate to it an impulse which is far from rapid, and as this fluid meets with only trifling obstacles, and such as are easily overcome, the pressure against the parietes of the veins is very inconsiderable, and these vessels do not pulsate, as the arteries. There is observed, however, near the heart, an undulatory motion which the blood communicates to the parietes of the vessels. These kinds of alternate pulsations depend on the rapidity with which the blood, whose course is progressively accelerated, flows towards the heart, and on the reflux of the blood, during the contraction of the right auricle. The contraction of this cavity, forces back the blood into the veins which open into it; this retrograde course is manifest in the superior cava, and is the more readily occasioned, as the orifice of this vein is not furnished with any valve that might prevent it. It does not, however, extend very far towards the brain, the blood having to ascend against its own weight, and the jugulars admitting of considerable dilatation. This regurgitation is still more marked in the inferior cava, the orifice of which is but imperfectly closed by the valve of Eustachius; it is felt in the abdominal veins, and extends even to the external iliacs, according to the testimony of Haller.

LXV. The orifice of the great coronary vein being exactly covered over by its valve, the blood does not return into the tissue of the heart, which being a contractile organ, would have had its irritability impaired by the presence of venous blood. It is of consequence to observe, that this reflux never extends to the veins which bring back the blood from the muscles, and that it is never felt in the veins of the limbs which are furnished internally with valvular folds. The case is very different, between our organs of motion and these secretory glands; towards these the blood required to be sent back, so as to be the longer exposed to their action: venous blood diminishes and even destroys muscular irritability, and is truly oppressive, as may be ascertained by injecting some, in the arteries of a living animal, or else by tying the veins, so as to prevent its return, or by observing what happens, when the course of the blood is interrupted, either by applying firm ligatures round the limbs, or by wearing confined clothes.

I am satisfied, that it was from observing the oscillatory undulations of the venous blood, in the great vessels, that the ancients were led to the opinions they entertained on the course of the blood, which they compared to the Euripus, whose waves are represented by the poets, as uncertain in their course, and in currents running in contrary directions.

The internal veins in which this reflux is observed, shew this motion of the blood most distinctly of any; their sides which are thin and semi-transparent, not being, as in other parts, surrounded by an adipose cellular tissue. To give a complete notion of the doctrine of the ancients, on the subject of the circulation, it will merely be necessary to add to the above idea, the opinion which they entertained, that the chyle taken up by the meseraic veins, was carried to the liver, in which its sanguification was effected, and lastly, that the arteries were filled with vital spirit, and contained only a few drops of blood which passed through small holes, which, Galen says, perforate the septum of the ventricles.

The blood, however, continually urged on by the columns which follow each other in succession, by the action of the veins whose parietes become gradually stronger, and by the compression which these vessels experience from the viscera, during the motions of respiration, reaches the heart, and enters the auricles with the greater facility, as the orifices of the cavæ not being directly opposed to each other, the columns of blood which they convey, do not meet and do not oppose each other.

LXVI. The blood, continually carried to all parts of the body by the arteries, returns, therefore, to the heart, by a motion which can never be interrupted, without considerable danger of life. We know, that the circulation is thus effected, from the direction of the valves of the heart, of the arteries and veins; by what happens, when these vessels are opened, compressed or tied, or when a fluid is injected into them. When an artery is wounded, the blood comes from the part of the vessel nearest the heart; it comes, on the contrary, from towards the extremities, if it is a vein that has been opened. By compressing or tying an artery, the course of the blood is suspended below the ligature, and the vessel swells above. The veins, on the contrary, when tied or compressed, dilate below. Lastly, when an acid fluid is injected into a vein, the blood is seen to coagulate in the direction of the heart. By the help of the microscope, we may see in the semi-transparent vessels of frogs and other cold-blooded animals, the blood flowing from the heart into the arteries, and from these into the veins which return it to the heart. It was on the strength of these convincing proofs, that William Harvey established, towards the middle of the sixteenth century, the theory of the circulation of the blood. Its mechanism had been rather guessed at, than understood, by several authors: Servetus and Cesalpinus appear to have been acquainted with it; but no one has more clearly explained it than the English physiologist, who is justly considered the author of that immortal discovery.

LXVII. The theory of Harvey, such as it is laid down in his work, entitled, *De sanguinis circuitu, exercitutiones anatomicæ*; does not appear to me entirely admissible.—He considers the heart as the only agent which sets the blood in motion, and does not take into account the action of the veins and arteries, which he considers as completely inert tubes, while every thing tends to prove that the arteries and veins assist the motion of the blood, by an action peculiar to themselves. He admits, that the blood flows, in every part of the circulatory system, with an uniform degree of speed; an opinion so manifestly contradicted by reasoning and experience, which prove that the velocity of its course diminishes, the greater its distance from the heart, from the influence of a great number of circumstances, which it would be useless to repeat (LVII.) This doctrine has yet, however, several abettors, and among the moderns, Spallanzani has endeavoured to support it, by a number of experiments so contradictory, that one is surprized, that so judicious a physiologist should have collected them to establish a theory completely refuted by several of them. Nothing, for example, contradicts it more fully, than the continuation of the flow of the blood, in the vessels of frogs and alamanders, after the heart of these reptiles have been torn out; there are besides, animals which not possessed of that central organ, have nevertheless, vessels along which the blood flows, and which contract and dilate, by alternate motions.

If the mere force of the heart propelled the blood to every part, the course of this fluid ought, at intervals, to be suspended, its circulation, at least, ought to be slackened, when the ventricles cease to contract; but as the contraction of the arteries corresponds to the relaxation of the ventricles, these two powers whose action alternates, are continually employed in propelling the blood along its innumerable channels.

Besides the general circulation of which the laws and phenomena have just been mentioned, each part may be said to have its peculiar mode of circulation, more or less rapid, according to the arrangement and structure of its vessels. Each of these individual circulations forms a part of the machinery included in the great circle of the general circulation, and in which the course of the blood takes place in a different manner, may be accelerated or retarded, without affecting the general circulation. Thus, in whitlow of a finger, the radial artery pulsates a hundred times in a minute, while on the sound side, its beats are only seventy in number, and perfectly isochronous with the pulsations of the heart. In the same manner, the blood of the intestines, which is destined to furnish the materials of the bile, flows much more slowly than that of other parts.

These modifications affecting the velocity of the circulatory motion of the blood, account for the difference of its qualities in different organs; all these differences form a part of the plan of Nature, and it is not difficult to understand their utility.

LXVIII. In what has been said of the circulation, no separate mention has been made of the course of the blood through the lungs, called by authors the lesser or pulmonary circulation. The vascular system of the lungs, with the addition even of the cavities of the heart which belong to it, does not represent a complete circle, it is only a segment, or rather an arch of the great circle of the general circulation.

The blood, in going along that great circle, meets with the organs, situated like so many points of intersection in the course of the vessels which form that circle.

To render still more simple, the idea which is to be entertained on the subject, one may reduce these intersections to two principal ones; the one corresponding to the lungs, the other to the rest of the body; the veins, the right cavities of the heart, and the pulmonary artery with its divisions, forming one half of the circle; the pulmonary veins, the left cavities of the heart, the aorta with all its branches representing the other half. The capillary vessels of the lungs form one of the points of intersection, and the capillaries of all the other organs, represent the other point of intersection, by uniting together the arteries and veins of the whole body, in the same manner as those of the lungs establish a communication between the veins and arteries of these organs.

This division of the system of circulation into two parts, in one of which there circulates a dark or venous blood, while the other contains red or arterial blood, is at once more simple and more accurate. As was already stated in the history of the circulation, its organs are, in an especial manner, destined to the mechanical act of conveying the fluids: the changes, the alterations which the blood undergoes in passing through the organs, are effected, only at the moment when in penetrating into their tissue, it passes into the capillary vessels which are distributed into them. The columns of blood are then sufficiently minute, to be operated upon by the vital action; till then, the columns of blood are too large, and resist, by their bulk, if one may so speak, any decomposition. It is, therefore, in the capillary vessels, that the blood receives its essential principles; and to understand how the nutritious lymph which is deposited by the thoracic duct into the left subclavian vein, experiences, in its course along the sanguiferous system, the changes which are to assimilate it to our own substance, it is necessary to follow it, along the venous blood with which it unites, into the heart, through the right half of which it passes in its way to the lungs, there to combine with the atmospherical air, from which we are perpetually deriving another aliment indispensable to life; then to examine, how, when modified and conveyed with the red blood, from the lungs to the whole body, it serves to the secretions, and supplies nourishment to the whole body.

In considering, in this manner, the circulation of the blood, with a reference to the changes which it undergoes in the organs through which it passes, in describing that circle, we shall find, that this fluid, already combined with the lymph and chyle, parts, in the lungs, with some of its principles, at the same time that it becomes impregnated with the vital portion of the atmosphere, which suddenly changes its colour and other qualities. The blood will then be seen to flow into all the parts which it stimulates, to keep up their energy, to awaken their action and furnish them the materials of the fluids which they secrete, or the molecules by which they grow or are repaired; so that in supplying thus the different organs, the blood loses all the qualities which it had acquired by the union of the chyle and of the vital air, parts with the principles to which it owed its colour, and again becomes dark, to be repaired anew by combining with the lymph, and by the absorption of the vital part of the atmospherical air; this constitutes the principal phenomenon of the function, which will be considered in the fourth chapter.

CHAPTER IV.

OF RESPIRATION.

LXIX. Of the different changes which the blood undergoes in the different organs, none are more essential or more remarkable than those it receives from the air, which, during respiration, is alternately received into the lungs and expelled from them. The blood which the veins convey to the heart, and which the right ventricle transmits to the lungs, is of a dark colour, and heavy; its temperature is only thirty degrees (Reaumur's thermometer); if laid by, it coagulates slowly, and there is separated from it a considerable quantity of serum. The blood which is brought by the pulmonary veins to the left side of the heart, and which is conveyed to all parts of the body, by means of the arteries, is, on the contrary, of a florid red colour; it is spumous, lighter, and warmer by two degrees. It likewise coagulates more readily, and contains a smaller quantity of serum. All these differences, which are so easily distinguished, depend on the changes which it has undergone, by being in contact with the atmospherical air.

LXX. *Of the atmosphere.* The mass of air which surrounds the globe, and to which we give the name of atmosphere, bears on all bodies with a pressure proportioned to their surface. That of man* bears a weight of air amounting to about thirty-six thousand pounds. Moreover, one of its constituent principles is absolutely necessary to the keeping up of life, of which it is a principal agent.

The variations in the weight of the atmosphere have, in general, but little influence on the exercise of the functions; nevertheless, when by ascending the tops of very high mountains, man rises several thousand fathoms above the level of the sea, the very remarkable diminution of the weight of the air, produces a very sensible effect. Respiration becomes laborious and panting, the pulse is quickened, and there is felt an universal uneasiness, joined to excessive weakness, and hemorrhages come on; these symptoms are occasioned both by the diminished pressure of the air, and by the smaller quantity of oxygen contained in a rarer atmosphere. (Saussure, *voyage au Mont-Blanc.*)

The human body resists, without any effort, the atmospherical pressure, because it is applied, at all times, and in every direction. But if a part of its surface ceases, for a moment, to be under its influence, it swells, the fluids are determined to it, in considerable quantity, the integuments become excessively distended, so as to be in danger of bursting; such are the phenomena which attend the application of cupping glasses.

The pressure of the air, on the surface of the globe, is necessary to the existence of bodies in the condition in which we see them. Several very volatile fluids, as alcohol and ether, would become gazeous, under a less pressure of the atmosphere; water would boil, under eighty degrees of temperature (Reaumur's scale); solid bodies themselves might become fluid. In a word, a considerable diminution in the weight of the atmosphere would have absolutely the same effect, as raising its temperature to a very great height, which, changing the face of the universe, would convert all liquids into elastic fluids, and would, doubtless, melt all solid bodies.

The variations in the weight of the atmosphere, distinguishable by the barometer, are of very little importance to the physiologist, and, I might even add, to the physician, notwithstanding the minute attention with which some writers note the state of the barometer, of the thermometer and hygrometer, and of the electrical state of the atmosphere, in giving an account of a disease or of an experiment, on which the above circumstances have no apparent or certain influence. The atmosphere, like every other fluid, has a perpetual tendency to a state of equilibrium, hence the rush of air into the lungs, or into other situations in which its quantity is diminished, by the combinations which it forms, or by the effects of heat which renders it lighter by rarefaction: the same principle explains the formation of the trade and other winds.

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* The surface of the body is estimated at fifteen or sixteen square feet, in a man of middle size.

The atmospherical air combines with water and dissolves it, as the latter dissolves saline substances. In this consists the process of evaporation. The air becomes saturated with water, in the same manner, as water becomes saturated with salt, to such a degree, as to be incapable of holding a greater quantity in solution. As its temperature rises, its solvent power increases, and the latter diminishes, as it grows cold; variations of temperature produce the same effect on solutions of salts in liquids. The formation of all the aqueous meteors, depends on the different conditions of the solvent powers of the atmosphere; when considerable, the atmosphere is warm and dry and the air serene; clouds form, when it is saturated; dews, fogs, and rain, are the consequence of a diminution of its solvent power, as snow and hail, of a degree of cold which recipitates the fluid. The different degrees of dryness or moisture, marked by the hygrometer, only sensibly affect the human body, when it has been exposed for a considerable time, to its influence.

Chemically considered, the atmospherical air, which was long regarded as a simple body, is composed of about 0,27 of oxygen, 0,73 of azote, and of 0,01 or 0,02 of carbonic acid. The proportions of oxygen, according to Humboldt, vary from 0,23 to 0,29; that of azote, is almost always the same; carbonic acid is the more abundant, as the air is less pure. This part of natural philosophy, which is called eudiometry, or the measurement of the purity of the air, is far from accomplishing what its name indicates, and has disappointed the hopes which had been entertained on the subject. Eudiometrical instruments can inform us, only of the proportion of oxygen contained in the atmosphere; now, its salubrity, its fitness for respiration, is not in proportion to the quantity of oxygen. The volatilized remains of putrid animal or vegetable substances, various mephitic gases, combine with it, and affect its purity. In the comparative analysis of air procured on the Alps and in the marshes of Lombardy, there was found in each the same quantity of oxygen; and yet, those who breathe the former, enjoy robust health, while the inhabitants of the marshy plains of Lombardy are carried off by epidemic diseases, are pale, emaciated, and habitually lead a languid existence.

Though, at least, 0,20 of oxygen are necessary to render the air fit for respiration, the proportion may be diminished to seven or eight parts in the hundred; but in such cases, the breathing is laborious, panting, and attended with a sense of suffocation, in short, asphyxia comes on, even while the air still contains a certain quantity of oxygen, of which the lungs cannot entirely deprive it. Whenever a number of persons are collected in a confined place, in which the air cannot be easily renewed, the quantity of oxygen diminishes rapidly, that of carbonic acid increases. The latter, in consequence of its specific gravity, sinks to the lowest part, and strikes with death every living being which it envelopes. When two lighted candles, of different lengths, are placed under the same bell, the shorter candle goes out first, because the carbonic acid formed during combustion, sinks to the most depending part. For the same reason, the pit is the most unhealthy part of a playhouse, when a great number of people, after remaining in it for several hours, have deprived the air of a considerable portion of its oxygen.

Persons collected together, and enclosed in a small space, injure each other, not only by depriving the atmosphere of its respirable element, but particularly by altering its composition, by the combination of all the substances exhaled from their bodies. These volatilized animal emanations, become putrid, while in the atmosphere, and conveyed to the lungs during respiration, become the germ of the most fatal diseases. It is in this manner, that the jail and hospital fever, so fatal to almost all whom it attacks, arises and spreads. A dry and temperate air, containing 0,27 of oxygen and 0,73 of azote, and free of other gasses or other volatilized substances, is the fittest for respiration. In certain cases of disease, however, this function is most freely performed in a less pure air. Thus, patients labouring under pulmonary consumption, prefer the thick and damp air of low situations, to the sharp and dry air of mountains; nervous women prefer that in which horn, feathers, or other animal substances are burning. An atmosphere highly electrical, at the approach of a storm, renders respiration very laborious, in some cases of asthma. In short, the qualities of the air must be suited to the condition of the vital power in the lungs, as those of the food, to the sensibility of the stomach.

Being obliged, on this subject, to content myself with the ungracious office of compiler, I hasten to bring this article to a close, and to refer the reader for a fuller account of the air, considered in its physical and chemical relations, to the works of M.M. Fourcroy, Hauy, Brisson, &c. to that of M. Guyton Morveau on the method of purifying the air, when from different combinations, it is become unfit for respiration.

LXXI. In man and in all warm-blooded animals, with a heart containing two auricles and two ventricles, the blood which has been conveyed to all the organs by the arteries, and which has been brought back, by the veins, to the heart, cannot return to it, without having previously passed through the lungs, which are viscera destined to the transmission of air; of a spungy texture, and through which the blood must, of necessity, circulate, to get from the right to the left cavities of the heart. This course of the blood contitutes the pulmonary or lesser circulation: it does not exist in some cold-blooded animals. In reptiles, for instance, the heart has but one auricle and one ventricle; the pulmonary artery, in them, arises from the aorta and conveys but a small proportion of the blood; hence the habitual temperature of these animals, it much lower than that of man. For the same reason too, there exists so small a difference, between their venous and arterial blood; the quantity of fluid vivified by exposure to the air, in the pulmonary tissue, being too small to effect, by its uuion with the general mass, a material change on its qualities.

Mayow has given the most accurate notion of the respiratory organ, by comparing it to a pair of bellows containing an empty bladder, the neck of which by being adapted to that of the bellows, should admit air on drawing asunder its sides. The air, in fact, enters the lungs, only when the chest dilates and enlarges, by the separation of its parietes. The agents of respiration are, therefore, the muscles which move the parietes of the chest, these are formed of osseous and soft parts, in such a manner, as to posses a solidity proportioned to the importance of the organs which the chest contains, besides a capacity of motion required to carry on the functions intrusted to them.

To carry on respiration, which may be defined the alternate ingress of air into the lungs, and its egress from those organs, it is necessary that the dimensions of the chest should be enlarged (this active dilatation of the cavity of the chest is called inspiration), and that it should contract to expel the air which it had received during the first process. This second action is called expiration, it is always of shorter duration than the former, its agents are more mechanical, and the muscles have much less influence upon it.

The parietes of the chest are formed, at the back part, by the vertebral column, at the forepart by the sternum, and on the sides, by the ribs which are osseo-cartilaginous arches, situated obliquely between the vertebral column which is fixed and becomes the point of support of their motions, and the sternum which is somewhat moveable—the spaces between the ribs are filled by muscular planes of inconsiderable thickness, the internal and external intercostal muscles, the fibres of which lie in opposite directions.—Besides, several muscles cover the outer part of the thorax, and pass from the ribs to the neighbouring bones: as the subclavian muscles, the great and lesser pectorals, the serrati, the latissimi dorsi, the scaleni, the longissimi dorsi, the sacro lumbales, and the serrati minores, posterior, superior, and inferior. But of all the muscles which form the anterior, posterior, and lateral parietes of the chest, the most important is the diaphragm, a fleshy and tendinous partition, lying horizontally between the chest and the abdomen, which it divides from each other; it is attached to the cartilages of the false ribs, and to the lumbar vertebræ, and has three openings to transmit the œsophagus and the vessels which pass from the abdomen to the chest, or from the latter into the abdomen.

In health, the chest dilates only by the descent of the diaphragm. The curved fibres of that muscle, straightened in contraction, descend towards the abdomen, and compress the viscera. The descent of the viscera thrusts forward the anterior parietes of that cavity, and these recede, when on expiration taking place after inspiration, the diaphragm now relaxed, rises, pressed upward by the abdominal viscera, compressed themselves by the large muscles of the abdomen. But when it is necessary to take into the chest a great quantity of air, it is not sufficient that it should be enlarged merely by the descent of the diaphragm, it is required besides, that its dimensions should be increased in every direction. The intercostal muscles then contract, and tend to bring together the ribs between which they are situated—The intercostal spaces however, become wider, especially at their anterior part, for, whenever lines falling obliquely on a vertical line, change their direction, approaching to a right angle, the intermediate spaces receive the greater increase, as the lines, more oblique at first, become at last more nearly horizontal. Besides, as the ribs are curved in the course of their length, in two directions, and both in the direction of their faces, and edgewise, the convexity of the first curvature is outwards, the ribs recede to a distance from the axis of the chest, whose cavity is enlarged transversely, while the second curvature (in the direction of their edge) being increased by a real twisting of these bones, and which reaches to the cartilaginous parts, the sternum is heaved forward and upward, so that the posterior extremity of the ribs is removed from their sternal end. But as the ribs are not all equally moveable, as the first is almost always invariably fixed, and as the others are moveable in proportion to their length, the sternum is tilted in such a way that the lowermost extremity is thrust forward. The diameter of the chest from the fore to the back part increases, therefore, as well as the transverse diameter. This increase of dimensions has been estimated at two inches, to each of these diameters; the dimensions of the vertical diameter, which are regulated by the depression of the diaphragm, are much greater.

LXXII. Professor Sabatier, in his memoir on the motion of the ribs, and on the action of the intercostal muscles, maintains, that during the act of inspiration, the upper ribs alone rise, that the lower ribs descend and slightly close on the chest, while the middle ribs project outwardly, and that in expiration, the former set of ribs descend, that the latter start a little outwardly and that the middle set encroach on the cavity of the chest. The learned Professor adds, that the cartilaginous articulating surfaces, by which the ribs are connected to the transverse processes of the vertebræ, appear to him to favour these different motions, as the direction of the articulations of upper ribs, is upward, and that of the lower, downward: but on considering the subject with attention, it will be seen, that the surfaces by which the transverse processes of the vertebræ are articulated to the tuberosities of the ribs, are turned directly forward in the greatest number, some of the lower ribs are, at the same time, directed slightly upward. If we examine the action of the bones of the chest, during inspiration, in a very thin person, for example, in phthisical patients, whose bones are covered with little else than skin, we shall find, that all the ribs rise and are carried somewhat outwardly. It is not easy to conceive how the intercostal muscles, which Professor Sabatier considers as the agents of expiration, should elevate the upper ribs and depress the lower. The diaphragm, whose circumference is inserted in the latter, might, by its contraction, produce this effect; but as the intercostals have their fixed point of action in the upper ribs, they oppose and neutralize this effort, and all the ribs are elevated at once. If this were not the case, the ribs ought to be depressed, whenever the intercostals contract, since the lowermost, fixed by the diaphragm, would become the fixed point on which all the others should move.

As the fibres of the external and internal intercostal muscles, are in direct opposition to each other, those of the former set of muscles having an oblique direction, from above downward, and from behind forward, and crossing the fibres of the other set whose obliquity is in a different direction; several physiologists have thought, that these muscles were opposed to each other, that the internal intercostal muscles brought together the ribs, after they had been separated by the external intercostals, the one set being muscles of expiration, while the other set contracted during inspiration.

It is well known with what pertinacity, Hamberger, in other respects, a physiologist of considerable merit, defended this erroneous opinion, in his dispute with Haller; it is now, however, ascertained, that all the intercostal muscles concur in dilating the chest, and that they ought to be ranked among the agents of inspiration, because the unequal capacity of motion in the ribs, prevents the internal intercostals, the lower insertion of which is nearer to the articulation of these bones to the vertebræ, from depressing the upper ribs. Of the very conclusive experiments, by which Haller undertook to refute the arguments of his adversary, I shall relate only that which is performed by stripping the parietes of the chest, in a living animal, of all the muscles which cover it, and by removing, in different parts of the thorax, some of the external intercostal muscles. The internal intercostals are then seen to contract during inspiration, together with the remaining external intercostals. These muscles, therefore, have a common action, and are not in opposition to each other. The same experiment serves to prove the increased dimensions of the space between the ribs. On holding one's finger between two of the ribs, it feels less confined, when during inspiration, these bones rise and thrust forward the sternum.

This question being at rest, although in the pursuit of science one should enquire *how* things are effected, and not, *wherefore* they come to pass, one feels naturally desirous to know what purpose is answered by the different direction of the fibres of the two sets of intercostal muscles; and with what view, Nature has departed from her wonted simplicity, in giving to their fibres opposite directions. In answer to this, one may observe, that the action of powers applied obliquely to a lever, being decomposed in consequence of that obliquity, a part of the action of the external intercostals would tend to draw the ribs towards the vertebral column, which could not happen, without forcing back the sternum, if the internal intercostals did not tend to bring forward the ribs, at the same time that they elevate them; so that these two muscular planes, united in their action of raising the ribs, antagonize and reciprocally neutralize each other, in the effort by which they tend to draw them in different directions.

To this advantage of mutually correcting the effects that would result from their respective obliquity, may be added the benefit arising from a texture capable of a greater resistance; it is clearly obvious, that a tissue whose threads cross each other, is firmer than one in which all the threads, merely in juxta position or united by means of another substance, should all lie in the same direction. Hence Nature has adopted this arrangement, in the formation of the muscular planes constituting the anterior and lateral parietes of the abdomen, without which the abdominal viscera would frequently have formed herniary tumours, by separating the fibres, and getting engaged between them. In this respect, one may compare the tissue of the abdominal parietes, in which the fibres of the external and internal oblique muscles, which cross each other, are themselves crossed by the fibres of the transversales, to the tissue of those stuffs whose threads cross each other, or rather to wicker work, to which basket-makers give so much strength, by interweaving the osier in a variety of directions.

LXXIII. When from any cause, respiration becomes difficult, and the diaphragm is prevented from descending towards the abdomen, or the motion of inspiration impeded, in any way, the intercostals are not alone employed in dilating the chest, but are assisted by several other auxiliary muscles; the scaleni, the subclavii, the pectorals, the serrati magni, and the latissimi dorsi, by contracting, elevate the ribs, and increase, in more directions than one, the diameter of the chest. The fixed point of these muscles then, becomes their moveable point, the cervical column, the clavicle, the scapula, and the humerus, being kept fixed by other powers, which it is unnecessary to enumerate. Whoever witnesses a fit of convulsive asthma, or of a suffocating cough, will readily understand the importance and action of these auxiliary muscles.

Inspiration is truly a state of action, an effort of contractile organs which must cease, when these are relaxed. The expiration which follows is passive, and assisted by very few muscles, and depends chiefly on the re-action of the elastic parts entering into the structure of the parietes of the chest. We have seen, that the cartilages of the ribs are pretty considerably twisted, so as to carry outward and downward their upper edge: when the cause which occasions this twisting ceases to act, these parts return to their natural condition, and bring back the sternum towards the vertebral column, towards which the ribs descend, from their weight. The diaphragm is forced towards the chest, by the abdominal viscera which are compressed by the broad muscles of the abdomen.

In every effort of expiration, as in cough and vomiting, these muscles re-act, not merely by their own elasticity, but they besides contract and tend to approach towards the vertebral column, by pressing upwards the abdominal viscera towards the chest. The triangularis sterni, the subcostales, and the serratus inferior posticus, may likewise be ranked among the agents of expiration; but they appear to be seldom employed, and to be too slender and weak to contribute much to the contraction of the chest.

LXXIV. When the chest enlarges, the lungs dilate and follow its parietes, as these recede from each other. These two viscera, soft, spungy, and of less specific gravity than water, covered by the pleura which is reflected over them, are always in contact with the portion of that membrane which lines the cavity of the thorax; no air is interposed between their surfaces (which are habitually moistened by a serous fluid exuding from the pleura) and that membrane, as may be seen, by opening, under water, the body of a living animal, when no air will be seen to escape. As the lungs dilate, their vessels expand, and the blood circulates through them more freely; the air contained in the innumerable cells of their tissue, becomes rarefied, in proportion as the space in which it is contained is enlarged. Besides, the warmth communicated to it by the surrounding parts, enables it, in a very imperfect manner, to resist the pressure of the atmosphere, rushing through the nostrils and mouth into the lungs, by the opening in the larynx which is always pervious, except during deglutition.

LXXV. The pulmonary tissue into which the air is thus drawn in, every time the capacity of the chest is increased, does not consist merely of air-vessels, which are but branches, of different sizes, of the two principal divisions of the trachea, but is formed, likewise, by the lobular tissue into which those canals deposit the air; it contains also a great quantity of lymphatics and blood vessels, of glands and nerves. Cellular tissue unites together all these parts, and forms them into two masses covered over by the pleura, and of nearly the same bulk*; suspended in the chest from the bronchiæ and trachea, and every where in contact with the parietes of the cavities of the chest, except towards their root, at which they receive all their nerves and vessels.

The pulmonary artery arises from the base of the right ventricle, and divides into two arteries, one to each lung. On reaching the substance of these viscera, these vessels divide into as many branches as there are principal lobes. From these branches, there arise others which again subdivide into lesser ones, until they become capillary, and continuous with the radicles of the pulmonary veins.

These vessels, formed from the extremities of the artery, unite into trunks, which progressively enlarging, emerge from the lungs, and open, four in number, into the left auricle. Besides these large vessels, by means of which, the cavities in both sides of the heart communicate together, the lungs receive from the aorta two or three arteries called bronchial arteries: these penetrate into their tissue and follow the direction of the other vessels and terminate in the bronchial veins, which open in the superior cava, not far from its termination into the right auricle. These bronchial vessels are sufficient for the nourishment of the pulmonary organ, which, in reality, is not nearly so bulky as it appears, as may be ascertained by examining the lungs, after all the air has been extracted from them, by means of an air pump, applied to the trachea.

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* It is well known that the right lung is larger than the left, that it is divided into three principal lobes, while the latter has only two.

Physiologists, for the most part, consider the bronchial arteries as the nutritious vessels of the lungs. They assert, that as the blood which flows along the branches of the pulmonary artery resembles venous blood, it is unfit for the nutrition of the lungs, and that it was necessary that these organs should be supplied by arteries arising from the aorta, and containing blood analogous to that which is sent to every part of the body. But though it be admitted, that this venous blood, brought from every part of the body, and sent into the lungs, by their principal artery, may not be fit to maintain the organ in its natural economy, this blood is fit for that use, when, after being made hot, spumous, and florid by the absorption of the atmospherical oxygen, it returns by the pulmonary veins, into the left cavities of the heart.

Some have thought, that the blood which flows in the bronchial vessels, exposed to the action of the air, like the portion of this fluid which traverses the pulmonary system, lost nothing of its arterial qualities, and that, poured by the bronchial veins into the superior or descending vena cava, it was a necessary stimulus for the right cavities of the heart, of which blood entirely dark and venous, would not have awakened the contractility. But even, if the experiments of Goodwin had not proved, that the parietes of these cavities have a sensibility relative to dark blood, by virtue of which, this stimulus is sufficient to determine their contraction, the action of the heart does not depend as closely as has been said, on the impression of the blood on its substance, since it contracts, though empty, and prolongs its contractions to relieve itself of the black blood which fills it, when an animal dies of asphyxia.

Boerhaave, who admitted one sort of peripneumony depending on the obstruction of the bronchial vessels, whilst another, according to the same writer, depends on the obstruction of the pulmonary vessels, seems to justify, in some measure, the reproach, exaggerated unquestionably, which some authors have thrown out against anatomy, of having rather retarded than accelerated the progress of the Hippocratic practice of medicine. The anatomical analysis of the lungs, or the distinction of the tissues which enter into their composition, furnishes juster ideas on the difference of the inflammations by which they may be attacked. It has been seen, that of these pulmonary phlegmasias, the commonest and least serious catarrh, consists in inflammation of the mucous membrane which lines the air passages, whilst the real peripneumony has its seat in the parenchyma of the organ, which it converts into a hard and compact mass. It is this state that anatomists have long designed under the name of *hepatization*, because, in fact, the substance of the lung has acquired the hardness, the weight, and something of the appearance of the liver. The same anatomical researches have shewn that pleurisy consists in inflammation of the pleura, and of the surface of the lung, an inflammation which sometimes leaves no trace, but which oftener exhibits, on the opening of bodies, the pleura thickened and opaque, covered with a layer of coagulable lymph, whitish, more or less thick or even adhering to the lung.*

There arise from the surface and from the internal substance of the lungs, a prodigious number of absorbents, which may be divided into superficial and deep seated. The latter accompany the bronchial tubes and penetrate into the substance of the glandular bodies situated where those air vessels divide, but collected, in greatest number, towards the root of the lungs and at the angle formed by the bifurcation of the trachea. These bronchial glands, belonging to the lymphatic system, do not differ from the glands of the same kind, and are remarkable only by their number, their size, and their habitually darkish colour. The absorbents of the lungs, after ramifying in these glands, terminate in the upper part of the thoracic duct, at the distance of a few inches from its termination into the subclavian vein. Lastly, the lungs, though endowed with a very imperfect degree of sensibility, have a pretty considerable number of nerves furnished by the great symphathetic, and especially by the eighth pair.

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* These adhesions of the lung to the pleura costalis, are so common, that the old anatomists considered them as a natural disposition, and called them ligaments of the lungs. It has been believed till now, that these adhesions arose from the organization of a substance transuding from the two surfaces. Numerous dissections have convinced me, that in all the points where they are met with, the pleura has disappeared, that it is decomposed, and that, whether it be at the surface of the lungs, or within the ribs and their muscles, it is produced by the act of inflammation, that it is become cellular, by the thinning of its tissue and the separation of its laminæ. The pleura thus reduced to cellular tissue, the adhesion is produced by the first intention, in the same way as in simple wounds immediately united. There is no organ that abounds more than the lungs in facts important to morbid anatomy. The variety of appearances they exhibit, on the opening of bodies, are almost innumerable; and to give one instance, the pleura appears after pleurisy in five perfectly distinct conditions. 1st. In its natural state, when the disease being incipient and slight, the resolution is effected at the moment of death.—2ndly. When it is red, thickened, and opake: 3dly. When it is covered with coagulable lymph:—4thly. When it adheres:—5thly. When, in consequence of chronic inflammation, hydrothorax has taken place, &c. &c.

It was long believed, on the authority of Willis, that the aerial tissue of the lungs is vesicular, that each ramification of the bronchiæ terminated in their substance, in the form of a small ampullula; but at present, most anatomists adopt the opinion of Helvetius. According to Helvetius, every air-vessel terminates in a small lobe, or kind of spunge fitted for the reception of air and formed of a number of cells communicating together.—These lobes, united by cellular tissue, form larger lobes, and these together form the mass of the lungs.

The tissue that connects together the different lobes is very different from that in which the ramifications of the bronchiæ terminate; air never penetrates in it, except when the tissue of the air cells is ruptured. On such occasions, which are not of rare occurrence, on account of the excessive thinness of the laminæ of the air cells of that tissue; the lung loses its form, and becomes emphysematous. Haller estimates at about the thousandth part of an inch, the thickness of the parietes of the air cells, and as the extreme ramifications of the pulmonary vessels are distributed on these parietes, the blood is almost in immediate contact with the air. There can be no doubt, that the oxygen of the atmosphere acts on the blood, under such circumstances, since it alters its qualities and communicates to it a florid red colour, when inclosed in a pig's bladder and placed under a vessel filled with oxygen gas.

LXXVI. Every time the chest dilates, in an adult, there enter into the lungs, between thirty and forty cubic inches of atmospherical air*, consisting, when pure, of seventy-three parts of azote, twenty-seven of oxygen, and one or two parts in the hundred, of carbonic acid.

When the air has been exposed, for a few moments, in the pulmonary tissue, it is expelled by the effort of expiration, but it is diminished in quantity and is reduced to thirty-eight inches. Its composition is no longer the same, it contains, it is true, 0,73 of azote, but the vital portion fit for respiration, the oxygen, has undergone a great diminution, its proportion is only 0,14: carbonic acid forms the remaining thirteen hundredths, and there are sometimes found one or two parts of hydrogen. It is besides affected by the addition of an aqueous vapour, which is condensed in cold weather, as it escapes at the mouth and nostrils. It is called the humour of the pulmonary transpiration. These changes, compared to those which the blood experiences in passing through the lungs, clearly show a reciprocal action of this fluid and of the oxygen of the atmosphere. The dark venous blood which coagulates slowly and which then disengages a considerable quantity of serum abounding in hydrogen and carbon, and of a temperature of only thirty degrees, yields its hydrogen and carbon to the oxygen of the atmosphere, to form carbonic acid and the pulmonary vapour: and as oxygen cannot enter into these new combinations, without parting with a portion of the caloric which keeps it in a state of gas, the blood acquires this warmth, which is disengaged the more readily, according to the ingenious experiments of Crawford, as by parting with its hydrogen and carbon, its capacity for caloric increases in the proportion of 10: 11.5.

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* Some physiologists think that the quantity of air inspired is much less considerable. Professor Gregory, of Edinburgh, states, in his public lectures, that scarcely two inches of air enter into the lungs, at each inspiration. It may be proved, however, that this calculation is inaccurate; either by drawing a full inspiration, as was done by Mayow, at the expence of a certain quantity of air contained in a bladder, or by breathing into a vessel connected with a pneuma-

In parting with its carbon which, by uniting with oxygen, forms the carbonic acid that is thrown out during expiration, the blood loses its dark and nearly purple colour, and becomes of a florid red, and its consistence increases, from the escape of its hydrogen and of its aqueous parts. Besides, as it absorbs a certain quantity of oxygen, it becomes spumous and light; its concrescibility and plasticity increase, and on coagulating, there is separated from it, a smaller quantity of serum.

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tic apparatus, the air taken in, by drawing a deep inspiration. Or else one may inflate the lungs of a dead body, by adapting to the trachea, a stop-cock connected with a curved tube to receive the air under a vessel of the same apparatus Various means have been employed to measure the capacity of the chest. Boerhaave placed a man in a tub containing water above his shoulders, he then made him take a deep inspiration, and measured the height at which the fluid rose from the dilatation of the chest. Keill injected water into the chest of a dead body. Lastly, it has been proposed to inject the bronchial tubes and the lobular tissue into which they terminate, with fusible metal consisting of eight parts of pewter, five of lead, three of bismuth, to which may be added one of mercury.

After parting with its hydrogen and carbon, and combining with oxygen and caloric, in its passage through the lungs, the blood, which is become arterial, parts with these two principles, in proportion as in receding from the heart, it forms new combinations, and is converted into oxides of hydrogen and carbon, which, on receiving an additional quantity of oxygen, are changed into water and carbonic acid, when on being carried along with the venous blood, into the pulmonary tissue, they are exposed to the influence of the atmospherical air.

The arterial blood becomes venous, by yielding its oxygen, when any cause whatever suspends or slackens its course, as is proved by the following experiment of John Hunter. He tied the carotid artery of a dog, with ligatures placed at the distance of about four inches from each other; the blood contained in the portion of artery included between the two ligatures, on laying open this part of the vessel, at the end of a few hours, was found coagulated and as dark as that in the veins. The blood contained in an aneurismal, sac, and which is frequently found in a fluid state, when the internal coats of the artery are but lately ruptured, becomes venous after remaining in it some time. The changes, however, which the blood undergoes in its course through the arterial system, are not very remarkable, owing to the rapidity with which it flows along those vessels; there is less difference between the blood contained in an artery near the heart, and that contained in an artery at a distance from that organ, than in the blood taken from the veins near their extremities, and from the great trunks which deposit it into the right auricle. The blood in the small veins resembles arterial blood, and frequently in a very copious bleeding, the colour of the blood, which, at first, is very dark, gradually becomes less dark, till towards the end of the bleeding, it shews nearly the same qualities as if arterial; a phenomenon which, as is well observed by the English writer already quoted, depends on the more easy and rapid flow of the blood of the arteries into the veins, in consequence of the evacuation of the venous system. This observation is a complete refutation of the assertion of Bellini, who maintains, that when a vein is wounded, the blood which comes from it, forms a double current which flows out at the wound. The above opinion is maintained by highly distinguished physiologists, as Haller and Spallanzani, who support it by experiments performed on the vessels of cold-blooded animals, or on veins without valves. In bleeding at the bend of the arm, the blood cannot come from that part of the vessel which is above the wound: the valves oppose insuperable obstacles to its retrogade flow, hence it is very easy to distinguish the red blood which comes from the lower extremity of the vein, from that which flows from the upper end, and which is poured into the vessel by the veins which open into it, between the puncture and the nearest valve.

In its course to the parts among which the arteries are distributed, the blood, vivified in its passage through the lungs, and fitted, as M. Fourcroy says, for a new life, loses its oxygen and caloric. Its capacity for the latter, diminishes, in proportion as the oxygen, by combining with hydrogen and carbon, restores it to the venous state.

This theory of the process by which the blood parts with its oxygen, in its progress along the blood vessels, is rendered still more probable, by recent discoveries on the nature of the diamond. This substance is the only pure carbon, and that which is called so by chemists, is an oxide of carbon which owes its dark colour to the oxygen with which it is combined. Before these experiments, it was not easy to determine the particular condition of the carbon which exists so plentifully in venous blood.

No precise calculation has yet been made, of the quantity of oxygen absorbed by the venous blood, nor of the quantity employed in the combustion of hydrogen and carbon in the lungs, so as to form water and carbonic acid.

Is the carbon, in venous blood, merely combined with oxygen, or is it united with hydrogen, so as to form carbureted hydrogen? It appears to me more probable, that the oxygen which is absorbed, by combining with hydrogen, in every part of the body, produces the water which dilutes the venous blood, renders it more fluid, and richer in serum than arterial blood; while, by its union with carbon, it forms an oxide that gives to the blood the dark colour, which is one of its most remarkable characters. On reaching the lungs, which are real secretory organs, the water is exhaled, dissolved in the air, and forms the pulmonary transpiration; the oxide of carbon, completely decomposed by an additional quantity of oxygen, constitutes carbonic acid, which gives to the air that is expired, the power of forming a precipitate in lime water.

The absorption of oxygen by the venous blood, explains how the phenomena of respiration are continued into every part of the body, and produce the warmth uniformly diffused over all our organs. In proportion as the blood parts with its caloric, for which its affinity diminishes as it becomes venous, the parts which give out their hydrogen and carbon, combine with it. If the lungs were the only organs in which caloric might be disengaged, the temperature of those viscera ought considerably to exceed that of other parts: experience, however, shews that the temperature of the lungs is not sensibly more elevated.

This theory of respiration, for which we are entirely indebted to modern chemistry, is contradicted by no one phenomenon. The greater the extent and capacity of the lungs, the more frequent is respiration, and the greater the warmth and vivacity of animals. Birds, whose lungs extend into the abdomen, by various membranous sacs, and whose bones are hollow and communicate with the lungs, consume a great deal of oxygen, either on account of the magnitude of this respiratory apparatus, or from their frequent, and, at times, hurried respiration. On that account, the habitual temperature of their body, exceeds that of man and mammiferous animals. In reptiles, on the contrary, whose vesicular lungs admit but a very small quantity of blood, and present to the atmosphere a surface of very limited extent, and in which respiration is performed with intervals of longer duration, the body is at a temperature which, naturally, never rises above seven or eight degrees.

LXXVII. Though the temperature or warmth of the body is generally proportioned to the extent of respiration, to the quantity of blood exposed, in a given time, to the action of the atmospherical air, it may be higher or lower, according to the degree of the vital energy of the lungs. These organs should not be considered as mere chemical receivers; they act on the air, digest it, as the ancients said, and combine it with the blood, by a power which is peculiar to them. If it were otherwise, there would be nothing to prevent a dead body from being restored to life, by inflating with oxygen its pulmonary tissue. The ancients alluded to this action of the lungs on the air we breathe, by calling that air the *pabulum vitæ.* Its digestion was, they thought, effected in the lungs, in the same manner as the digestion, in the stomach, of other aliments less essential to life, and whose privation may be borne for a certain time, while life is endangered, when the aeriform nutriment ceases to be furnished to the lungs, for the short space of a few minutes.

In proof of the vitality of the lungs, and of the share which they have in producing the changes which the blood undergoes in passing through them, I may mention the experiment which proves that an animal placed under a vessel filled with oxygen, and breathing that gas in a pure state, consumes no more of it, than if it was received into the chest, mixed with other gasses unfit for respiration. A guinea-pig, placed under a vessel full of vital air and of known capacity, will live four times longer than if the vessel contained atmospherical air. No remarkable difference is at first perceived in the act of respiration, but if the animal remains long immersed in the oxygen, his respiration becomes more frequent, his circulation more rapid, all the vital functions are executed with more energy. The lungs separate, by a power inherent in themselves, the two atmospherical gasses, and this process is effected by a pretty considerable power, for, oxygen, in its combination with the blood, is, with difficulty, separated from azote. In fact, the blood, though in thin layers, becomes dark, when exposed to the atmospherical air.

It is observed, that the purity of the air contained in the receiver, is the more readily affected, as the animal placed under it is younger, more robust, and as his lungs are more capacious. Hence birds, whose lungs are very large, contaminate a considerable quantity of air, and consume more quickly its respirable part. A frog, on the contrary, will remain a considerable time, in the same quantity of air, without depriving it of its oxygen.

The vesicular lungs of that reptile, as well as of all oviparous quadrupeds, are much more irritable than those of warm-blooded animals; they appear to contract, at the will of the animal. The frog is without a diaphragm, attracts the air into its lungs, by swallowing it by a real process of deglutition, as was proved by Professor Rafu, of Copenhagen, who killed those animals by holding their jaws asunder for a certain time. They reject the air by a contraction of the lungs, in the same manner as in man, the bladder empties itself of urine.

In birds, whose diaphragm is equally membranous, and contains several openings to transmit the air into the pulmonary appendices, the parietes of the thorax are likewise more moveable than in man and quadrupeds. Their pectoral muscles are more powerful, their ribs contain a joint situated in the middle of those arches which are completely ossified in that class of animals; and those two portions move on each other, forming, at their point of union, angles more or less acute, according to the distance of the sternum from the vertebral column.

A numerous class of cold- red-blooded animals, viz. fishes, have no lungs; the gills, which supply their place, are small penniform laminæ, generally four in number, situated on each side, at the posterior and lateral part of the head, covered over by a moveable lid, to which naturalists give the name of operculum. The water which the animal swallows, passes, when he chooses, through the parietes of the pharynx, which contain several pretty considerable openings, is spread over the gills and the pulmonary vessels which are distributed in them, then escapes at the auricular apertures, when the animal closes his mouth, and raises the opercula. It is not known, whether the water is decomposed and yields its oxygen to the blood which circulates in the gills, or whether the small quantity of air that is dissolved in the water, alone serves to vivify the pulmonary blood. The latter opinion seems the most probable, if it be considered that a fish may be suffocated, by closing accurately the vessel of water in which it is enclosed. The same result, might, I conceive be obtained, by placing the vessel under the receiver of an air pump, so as to exhaust it completely.

Respiration, which is completely under the influence of the brain, as far as relates to its mechanism, is less dependent upon it, in regard to the action of the lungs on the blood, and the combination of that fluid with oxygen, which is the essential object of that function. The nerves, however, have some influence on that function, as well as on the various secretions, in which, according to Bordeu, they are of first-rate importance. M. Dupuytren ascertained by his experiments, that the division of the cervical portion of the eighth pair of nerves, did not sensibly affect respiration; but the animal died with all the symptoms of asphyxia, when this nerve was divided on both sides. Death took place, in the course of a few minutes, when the experiment was performed on horses. Other animals did not die so soon after; dogs, for instance, have been known to live several days after the experiment. By interrupting the communication between the lungs and the brain, we paralyze the former of these organs, and it ceases to convert the venous into arterial blood. This fluid, conveyed by the pulmonary artery, continues of a dark colour, when brought to the left cavities of the heart; the arteries convey the blood without its having received its vivifying principle, in passing through the lungs which are paralyzed, by having their nerves tied or divided. It is easy to conceive that all organs, for want of the stimulus which determines their action, carry on their functions imperfectly, and at last cease to act. The animal heat is likewise lowered a few degrees, as was ascertained by the above-mentioned physician, who thinks he has established as a fact, that the ligature of the nerves of the lungs does not destroy, but weakens the vital power, which enables them to take up the oxygen and to give out the carbonic acid. The brain, therefore, possesses a double influence over the function of respiration; on the one hand, it directs its mechanism, by means of the nerves which it sends to the diaphragm, and to the intercostal muscles, and on the other hand, it is through the nerves which arise from the brain, that the lungs have the power of converting dark blood into arterial blood, which is the principal phenomenon of respiration.

Experiments performed on the same subject, by Dr. Gallois, subsequent to those I just related, tend to throw some degree of uncertainty on their results. Dr. Gallois repeated these experiments publicly, in my presence, and at the society of the Ecole de Médecine of Paris. After dividing the two nerves of the eighth pair, in a guinea-pig, and after having, by that process, brought on a state of asphyxia, he restored life and motion to the animal, by opening the trachea at its anterior part. The blood of the carotids, which from red had become dark the moment the nerves were divided, recovers immediately its red colour, the motion of respiration is restored, and the animal lives several days after the experiment. Whence does this difference arise; does the division of the eighth pair bring on asphyxia, by occasioning a spasmodic constriction of the glottis, and by impeding, or even completely obstructing the admission of the atmospherical air?

LXXVIII. *Of animal heat.* The human body, which is habitually of a temperature of between thirty-two and thirty-four degrees of Réaumur's thermometer, preserves the same degree of warmth under the frozen climate of the polar region, as well as under the burning atmosphere of the torrid zone, during the most severe winters and the hottest summers. Nay further, the experiments of Blagden and Fordyce in England, and of Duhamel and Tillet in France, shew, that the human body is capable of enduring a degree of heat sufficient to bake animal substances. The Fellows of the Academy of Sciences, saw two girls enter into an oven, in which fruits and animal substances were being baked; Réaumur's thermometer which they took in with them, stood at 150 degrees; they remained several minutes in the oven, without suffering any inconvenience.

All living bodies have a temperature peculiar to themselves, and independent of that of the atmosphere. The sap of plants does not freeze, when the thermometer stands only at a few degrees below zero; on placing the bulk of a thermometer in a hole in the trunk of a tree, during winter, the fluid sensibly rises. Now, three circumstances remain to be investigated: in the first place, what produces in living bodies, this inherent and independent temperature? In the second place, how do these bodies resist the admission of a greater degree of heat, than that which is natural to them? What prevents caloric, which has a perpetual tendency to a state of equilibrium, from passing into a body surrounded by a burning atmosphere? Lastly, how does a body which resists the influence of heat, withstand equally, the destructive influence of an excessive degree of cold.

LXXIX. Caloric, in a latent state, or in combination with bodies, is disengaged from them, whenever they assume a different state; when, from a gazeous form they become liquid; or when from being liquid, they become solid. Now, living bodies are a kind of laboratories in which all these changes are perpetually going on; the blood which circulates in every part of the human frame, is constantly receiving supplies of fresh materials; from the thoracic duct which pours into it the chyle, abounding in nutritious particles; from respiration which imparts to it an aeriform principle obtained from the atmosphere; and even, in some cases, from cutaneous absorption, through which different elements are received into it. All these different substances carry along with them into the blood, a certain quantity of caloric, which is combined with them, and which is disengaged during the changes which they undergo, from the influence of the action of the organs, and gives out its caloric to the parts among which it is disengaged. Of all the principles in the blood, which have the power of communicating heat to the organs, none furnishes a greater quantity than oxygen, which, during respiration, combines with the blood in the lungs. Gazeous substances, it is well known, contain most combined caloric; their state of elastic fluidity, is entirely owing to the accumulation of that principle, and they part with it, when from any cause whatever, they become liquid. It is on that account, that the heat of bodies is greater, the more they have the power of impregnating their fluids with a considerable quantity of oxygen from the atmosphere. For the same reason, as was already observed, in animals that have cellular lungs, and a heart with two ventricles, the blood is of the same temperature as in man; and such animals belong, as well as man, to the great class of *warm- red-blooded animals;* a class in which birds occupy the first place, from the vast extent of their lungs, which reach into the abdomen, and communicate with the principal bones of the skeleton. The capacity of the pulmonary organ of birds, is not the only cause why their temperature is eight or ten degrees higher than that of man; this increase of temperature depends, likewise, on the greater frequency of their respiration, and on the velocity of their pulse; on the quickness and multiplicity of their motions, and on the vital activity which animates them. In reptiles which have vesicular lungs, and a heart with a single ventricle, whose respiration is slow, and performed at distant intervals, the blood, though red, is of very inferior temperature to that of man. They have, from that circumstance, been called cold- red-blooded animals; this numerous class includes fishes, which possess an organ supplying but imperfectly the office of lungs. In fishes, the heart which has but a single ventricle, sends, it is true, to the gills (the organ supplying the place of lungs is so called) the whole of the blood; that fluid, however, is but imperfectly vivified in the gills, on account of the small quantity of air which can be taken in during the act of respiration. Lastly, in white-blooded animals and in plants, the combinations with the air being more difficult, the vital energy less marked, the temperature differs only by a few degrees, from that of the atmosphere, and they do not endure heat or cold, so well as the more perfect animals.

The lungs, as was before observed, consuming only a certain quantity of air, there is no increase of temperature, however great the quantity of oxygen contained in the atmosphere that is breathed, as a man who should take a double quantity of aliment, could not receive more nourishment, than if he contented himself with the quantity of food proportioned to his wants; for, as the digestive organs can extract only a certain quantity of chyle, the quantity of recrementitious matter would only be greater, if more than the due quantity of food were received into the stomach. Hence the common saying, that nourishment comes from what we digest and not from what we eat.

The pulmonary organ may, however, act on the air, with different degrees of power, in robbing it of its oxygen; and when the body becomes of an icy coldness, in certain nervous and convulsive affections, this cold may depend as much on the atony of the lungs, and on the spasmodic condition of the chest, which, dilating with difficulty, does not admit the air readily, as on the spasm and general insensibility of the organs, which allow the blood to pass without affecting its component parts. It would be curious to ascertain, whether the air expired from the lungs of a cataleptic, contains more oxygen, is less impaired, and contains a smaller quantity of carbonic acid than the breath of a sound active adult. Perhaps it would be found, that in catalepsy and other similar affections, the blood does not part with its hydrogen and carbon, that it retains its colouring principles, and the different materials of the urine, which is voided in a colourless and limpid state, insipid and without smell, and in the condition of a mere serosity.

The temperature of the body is produced, not only by the pulmonary and circulatory combinations; it is besides developed in several organs, in which fluid or gazeous substances become solid, by parting with a portion of their caloric. Thus digestion, particularly of certain kinds of food, is an abundant source of caloric; the skin which is habitually in contact with the atmosphere, decomposes it and deprives it of its caloric.—Lastly, caloric is produced and evolved in all parts whose molecules, affected by a double motion in consequence of which they are incessantly being formed and decomposed, by changing their condition and consistence absorb or disengage more or less caloric. The great activity of the power of assimilation in children, is, no doubt, the cause of the habitually high temperature, at that period of life. The temperature of the body is not only one or two degrees higher at that period of life; but young people, after death, preserve, for a longer period, the remains of vital heat; or rather, as tonicity does not so soon forsake the capillary vessels, life departing reluctantly, the combinations from which caloric is evolved, continue some time, even after it is extinct. For the same season, the bodies of persons that have died suddenly, retain their warmth, long, while an icy coldness seizes the bodies of those who have died of a lingering disease, from the slow, gradual and total abolition of the powers of life.

Calorification, or the disengaging of animal heat, like nutrition, takes place at all times, and may be considered as belonging to all organs. It was of the utmost consequence, that the internal temperature of the human body should be nearly the same at all times. For, let us, for one moment, suppose, that the temperature of the blood should rise to fifty degrees of Réaumur's thermometer, its albuminous parts would suddenly coagulate, obstruct all the vessels, interrupt the circulation and destroy life. When, therefore, from an increased activity of the nutritive combinations, a greater quantity of heat is disengaged, the animal economy parts with it, and it is taken up, in greater quantity, by the surrounding bodies. This accounts for the equality of the temperature of the internal parts of the body, in old people and in children, notwithstanding the difference of their temperature externally. The difference consists in this, that where most caloric is produced, most is given out, and though the blood and urine in old people, as well as in the young, are at thirty-two degrees, what a difference is there not, between the hot and penetrating perspiration which is poured in abundance, from the child, and the dryness and coldness of the skin in old people; between the sweet and warm breath of the former, and the frozen breath of the latter! Hence the opinion so generally received and of such antiquity, that old people are benefited by cohabiting with the young. Thus, we are told, that David had a young virgin brought to him, that he might lie with her, and get heat in his limbs that were stiffened with years.

If it be true, that in the very act of nutrition, which converts our fluids into solids, there is disengaged a considerable quantity of caloric; the motion of nutritive decomposition, by which our solids are converted into liquids, must cause an equal quantity of heat to be absorbed. The objection is a very strong one, and not easily got over; it may be answered, by observing, that all living bodies, from the instant of their formation, contain a certain quantity of caloric which they retain, so that this double process of acquiring heat and parting with it, the unavoidable result of nutritive composition, and decomposition, merely keeps up an equilibrium and maintains the same degree of temperature.

The blood which becomes saturated with oxygen, in the capillaries of the lungs, parts with that principle, and disengages its caloric, throughout the capillary vessels of the whole body, of which each organ must set free a greater quantity, in proportion to the activity of the living principle, and to the rapidity of the circulation. The parts through which the greatest number of vessels circulate, perhaps give out most caloric, and communicate a portion of it to the organs, which receive but a small quantity of blood, as the bones, the cartilages, &c. It is easy to understand, why an inflamed part, through which the blood circulates with more rapidity, and whose sensibility and contractility are much increased, is manifestly hotter to the feel of the patient and of the physician, though, as was observed by John Hunter, a thermometer applied to the inflamed part, shews a scarcely perceptible increase of temperature. He injected into the rectum of a dog, and into the vagina of an ass, a strong solution of oxymuriate of mercury. Acute inflammation came on, the swollen mucous membrane formed, externally, a considerable projection. Blood flowed from the torn capillaries, yet the thermometer rose very slightly, only one degree of Farenheit's. But however slight that increase of heat in the inflamed part, it is very sensibly felt, on account of the extreme sensibility of the organ, whose vital properties are all increased. The liveliness of impressions being proportionate to the degree of the power of sensation, one need not wonder that the patient should experience a sensation of burning heat, in a part in which the thermometer indicates no increase of temperature, in which it cannot be perceived even by the touch. I have just felt a young man's hand, that is swollen from chilblains; though the pain which he feels in it, seems to him to be occasioned by an accumulation of caloric; his hand is colder than mine, which is of the same degree of warmth as the rest of my body, and in which I have no peculiar sensation. It may, therefore, be laid down as an axiom, that the real or thermometrical increase of heat is inconsiderable in inflammation, but that it is intensely felt, in consequence of the increase of sensibility.

What is the reason, that during the cold fit of a febrile paroxysm, a sensation of excessive cold is felt in a part in which no diminution of heat can be discovered by the touch? Whence comes the burning heat which attends inflammatory fever *(causos)*? What is the cause of the difference of the sensations attending the heat of erysipelas, bilious fevers and phlegmon, &c.? These various sensations are owing to the different modifications of sensibility in these different diseases. Should this explanation appear unsatisfactory, let it be recollected, that however accurate the calculations may be, that have been made on the subject of caloric or of the matter of heat, the existence of caloric itself is hypothetical, and that it is not known, whether caloric is a body, or whether heat is merely a property of matter.

LXXX. If we now inquire into the causes which enable the body to resist the admission of a degree of heat superior to that which habitually belongs to it, we shall be compelled to admit, in all living bodies, a power by means of which they repel an excess of heat, and retain the same temperature. Cutaneous perspiration, it is true, acts very powerfully in lowering the temperature, and as this evaporation increases with the temperature, it should seem as if this function sufficed to moderate the heat of the body, and to restore the equilibrium.

It is a fact known since the time of Cullen,* that the evaporation of fluids, or their solution in the air, is the most powerful means of cooling bodies, and that the mercury in the bulb of a thermometer, may be frozen merely by moistening it with æther, spirits of wine, or any other volatile substance, and then exposing it to a dry and warm air.—This method is equally successful in its application to the human body, and the hands may be cooled to such a degree, as to feel benumbed, by being frequently wetted with a spirituous fluid, and by being moved in a dry and renewed air. But though cutaneous perspiration operates in a somewhat similar manner, and though it may be ranked among the means which nature employs to preserve the animal temperature in a nearly uniform state, it must however be confessed, that it is not the only way in which this object is accomplished, and that it does not satisfactorily account for this phenomenon, for, the evaporation of the fluids contained in dead animal substances, does not prevent their being roasted on the application of heat, and besides, fishes and frogs have been known to live and retain their temperature in mineral waters, nearly of a boiling heat.†

I thought it right to repeat these experiments, and with this view, I placed living frogs in a vessel containing water at fifty degrees of temperature, and on taking them out, at the end of ten minutes, I ascertained that they were not so hot as the liquid, nor as pieces of flesh which had been put into it at the same time.

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* This celebrated physician made this discovery about forty years ago, which has thrown much light on several physico-chemical phenomena, and he published it in a dissertation entitled: "Of the cold produced by evaporating fluids, and of some other means of producing cold, by Dr. W. Cullen."

† *See Sonnerat's voyage to the East Indies.*

We cannot admit the opinion of Grimaud, that living bodies have the power of producing cold; for, as cold is merely the absence of heat, one cannot allow a positive existence to a negative being.

Habit has a remarkable influence on the faculty which the body possesses, of bearing a degree of heat, much exceeding that which is natural to it. Cooks handle burning coals with impunity; workmen employed in forges, leave the mark of their feet on the burning and liquid metal, at the moment when it becomes solid by cooling. Many, no doubt, recollect the too famous instance of a Spaniard, who became so general a subject of conversation in Paris: this young man, in making his way through a house on fire, perceived that the heat was less inconvenient to him than he had imagined. He applied himself to bear, with impunity, the action of fire, and was enabled to apply to his tongue a spatula heated red hot, and to apply the soles of his feet and the palms of his hands on a red hot iron, or on the surface of boiling oil. Nothing can equal the absurdity and the exaggeration of the stories that were told of this man, except the ignorance and the want of veracity of those who invented them.—The following is a correct statement of the feats of this man, who was represented as incombustible and insensible. He passes rapidly along the surface of his tongue, which is covered with saliva, a red hot spatula, the action of which seems merely to dry it, by bringing on an evaporation of the fluids with which it is covered. After carrying the spatula, from the base to the tip of his tongue, he brings it back again into his mouth, and applies it to his palate, to which it communicates a part of its heat, at the same time that it becomes moistened with saliva. This man having, in a public exhibition, carried on, too long, the application of the spatula, the caustic effects of its heat shewed themselves, the epidermis was detached, and found coiled, like the outer covering of an onion, in the cloth which he used to wipe his mouth. He does not dip his hands and feet in boiling oil, he merely applies to the surface of the fluid, his palms and his soles, and he repeats this frequently, with only a short interval between each application. When the experiment is carried on, for a certain length of time, there is emitted a smell of burnt horn. No one has yet observed, that though this man's hands are not callous, the palms of these, and the soles of his feet are cushioned with fat. A thick layer of fat, which is a bad conductor of heat, separates the skin from the subjacent aponeuroses and nerves; this circumstance, to a certain degree, accounts for his imperfect sensibility.

His pulse, during those experiments, was about a hundred and twenty; the perspiration evidently increased, and sometimes copious. Every part of his body possesses the ordinary degree of sensibility, may be destroyed by the protracted application of caustic substances, and would be consumed by fire, if applied for a sufficient length of time, and nitric acid would infallibly destroy his tongue if he took any into his mouth, as it has been said he did. This man, therefore, in no one respect departs from the known laws of the animal economy, but, on the contrary, affords an additional proof of the influence of habit on our organs.

LXXXI. Before bringing to a conclusion this article on animal heat, it remains for me to explain how the body resists cold, and preserves its temperature, in the midst of a frozen atmosphere. This cannot be accomplished without an increase of activity in the organs, it is only by augmenting the sum of the combinations by which caloric is disengaged, that we can succeed in making up for the loss of that principle so necessary to our existence.—What is the reason that in cold weather, digestion is more active (*Hieme verò ventres sunt calidiores.* Hipp.), the pulse stronger and more frequent; and the vital energy greater? It is because heat comes from the same source, and is produced by the same mechanism as the nutrition of the organs; and that its evolution may go on increasing, it is necessary that the secretions, nutrition, in a word, all the vital functions, should increase, in the same proportion.

Observe, for a moment, a man who is exposed to a moderate degree of cold, he feels more activity, more strength, and is more nimble, he walks and exerts himself, the most violent exertions do not appear to him laborious, he struggles against the disadvantages of the debilitating influence; and provided the cold is not excessive and the body tolerably vigorous, there is disengaged, within himself, a sufficient quantity of caloric to make up for the loss of that which is caried off by the air and the surrounding bodies. These general effects of cold are not disproved by what happens, when only a part of the body is exposed to it. Supposing the temperature a few degrees below zero, there is felt, at first, a sensation of cold much more inconvenient, cæteris paribus, than if it acted on a more extensive surface. The spot on which the cold air acts, becomes affected with a painful sense of pricking, reddens, then inflames; and in this case, inflammation is evidently the result of a salutary effort of nature which determines into the inflamed part, an excess of the vital principle, so that the quantity of heat that is disengaged may correspond to that which has been abstracted. The effort of this conservatory principle is more marked, than if the whole surface of the body were at once exposed to cold, because, acting wholly on a limited point, of small extent, it operates with more intensity.

Beyond a certain degree, however, nature in vain struggles against cold; if severe, and if the creature exposed to it, have not the power of sufficient reaction, the part becomes purple and benumbed from the loss of its caloric, vitality ceases, and it mortifies; and if the whole body is equally exposed to the influence of cold, the person is benumbed, feels a stiffening of his limbs, stammers, and overpowered by an irresistible propensity, yields to a sleep which inevitably ends in death. By yielding thus to the illusive sweets of a perfidious sleep, many travellers have perished after losing their way, in the mountains of the old and of the new world. Thus, two thousand soldiers of Charles the twelfth's army perished, during a siege, in the severe winter of 1709.

To resist the effects of cold, a certain degree of strength and vigour is therefore necessary; it is consequently very injudicious to recommend the cold bath to very young children, to delicate and nervous women, to persons whose constitution is not capable of a sufficient reaction. The evil attending the injudicious use of this remedy in the cases that have just been enumerated, justifies the apparently singular terms in which Galen expressed himself: "Let the Germans (says this first of physiologists) let the Sarmatians, those northern nations as barbarous as bears and lions, plunge their children in frozen water; what I write is not intended for them."

On the other hand, if it be recollected, that there is within us a power of reaction, which increases with use, that motion strengthens our organs, it will be readily understood, that cold acts as a tonic, whenever it is not applied to such a degree, as to extinguish the vital power.

The manner in which enlightened physicians have, at all times, prescribed the cold bath, shews that they were acquainted with this tonic effect depending, not on the application of cold, which in itself is debilitating, but on the reaction which it occasions. Hence along with the cold bath, they are in the habit of recommending exercise, a generous wine, bark, nutritious food, and an analeptic regimen, calculated to excite a salutary reaction.

LXXXII. Animal heat is, therefore, produced by the combinations of our fluids and solids in the process of nutrition; it is a function common to all the organs, for, as they all nourish themselves, so they all disengage, more or less, the caloric combined with the substances which they apply to their nutrition.

Though we are without precise information respecting the manner in which a living body resists the admission of a degree of heat exceeding that which is natural to it, one may consider cutaneous exhalation, which is increased by the use of heating substances, as the most powerful means employed by nature to get rid of the excess of heat, and to restore the equilibrium.

Lastly, the body resists cold, because the organs being rendered more active by cold, there is disengaged a quantity of caloric equal to that which is carried off by the air, or by the other substances with which the body happens to be in contact.

LXXXIII. The rapidity of the circulation of the blood through the lungs, is equal to the velocity with which it flows in the other organs. For, if on the one hand, the parietes of the right ventricle and of the pulmonary artery, are weaker and thinner than those of the left ventricle and aorta, the lungs, from their soft, easily dilated, and spungy texture, are the most easily penetrated by fluids of all our organs.

The right ventricle sends into the lungs a quantity of blood, equal to that which each contraction of the left ventricle propels into the aorta, and it is not necessary to adopt the opinion of M. Kruger, that each contraction of the heart sends into the lungs and into the rest of the body an equal quantity of blood, for, in that case, the circulation would have been much slower, the length of the lungs being much shorter than the whole body. Nor need we say, with Boerhaave, that this circulation is much more rapid, because the same quantity of blood returns by the extremities of the pulmonary artery, and of all the other arteries of the body.

The extension of the pulmonary tissue, the straightening of its vessels are, no doubt, favourable to the circulation of the blood, but if the admission of air did not answer a different purpose, the circulation would not be indispensably necessary. The blood flows from the right into the left cavities of the heart, notwithstanding the collapse of the lungs and the creases of their vessels. The air which penetrates, at all times, into the lungs, supports their tissue and the vessels which are distributed to it, so that even during expiration, the vessels are much less creased, than has been imagined by several physiologists. But the changes produced by the contact of the atmosphere, renovate this fluid, and fit it to re-excite and keep up the action of all the organs, which require to be stimulated by arterial blood. If you make a living animal breathe de-oxygenated air, the blood undergoes no change by its pulmonary circulation: the left cavities of the heart are no longer duly irritated by this fluid, which preserves all its venous qualities; their action becomes languid, and with it that of all the organs; and in a little while, it ceases altogether. It is revived by introducing pure air, through a tube fitted to the trachea; all the parts seem to awake out of a sort of lethargic sleep: in which they are again immersed, by depriving the lungs anew of the vital air.

The chyle, mixed in great quantity with the venous blood, undergoes, in its passage through the heart and the sanguineous system, a more violent agitation: its molecules are struck together, break on each other, and, thus attenuated, become more perfectly intermingled: in its passage through the lungs, a great part of this recrementitious fluid is deposited by a sort of internal perspiration, in the parenchymatous substance of these viscera. Oxydated by the contact of the air, re-absorbed by a multitude of inhalant vessels, it is carried into the bronchial glands, which are found blackened by what it there deposits of carbonic and fuliginous matter. Purified by this elaboration, it returns into the thoracic duct, which pours it into the subclavian vein, whence it soon returns to the lungs, to be there anew subjected to the action of the atmosphere: so that there is effected, through these organs, a real lymphatic circulation, of which the object is to bring on the chyle to a higher decree of animalization.

LXXXIV. *Of pulmonary exhalation.* It will be remembered, that one of the great differences between the blood of the arteries, and that of the veins, consists in the great quantity of serum found in this last. It is in the lungs that the separation of this aqueous part takes place, and that its proportion is reduced, whether it be, that oxygen gives albumen and gelatine a greater tendency to concrete, or that the serum, formed by the fixation of oxygen throughout the whole extent of the circulatory system, exhales from the arteries, and thus furnishes the matter of pulmonary exhalation. It is scarcely possible to admit the combination of oxygen with the hydrogen of the venous blood, and that water is thus formed from its elements, as happens when storms are gathering in the high regions of the atmosphere. If a similar process can be carried on in the lungs, without producing deflagration and the various phenomena attending the production of aqueous meteors, it is probable, that it furnishes but a small part of the exhalation; and that this humour, analogous to the serum of the blood, exhales, completely formed, from the arterial capillaries ramified in the bronchiæ and the lobular tissue of the lungs. It is believed, that the quantity of the pulmonary exhalation is equal to that of the cutaneous exhalation (four pounds in twenty four hours). These two secretions are supplemental to one another: when much water passes off by the pulmonary exhalation, the cutaneous is less, and *vice versâ.*

The surface, from which the pulmonary exhalation is given out, is equal, if not superior in extent to that of the skin; exhalation and absorption are at once carried on from that surface, many nerves are distributed to it, and are almost exposed in the tissue of the membranes which are extremely thin. Are the miasmata with which the atmosphere is sometimes loaded, absorbed by the lymphatics, which, it is well known, have the power of taking up gazeous substances; or do they merely produce on the nervous and sensible membranes of the bronchiæ, and of the lobular tissue, the impression whence the diseases of which they are the germ arise?

A part of the caloric which is disengaged in the combinations which oxygen undergoes in the lungs, is taken up in dissolving and reducing into vapour, the pulmonary exhalation, which is the more abundant, according as respiration is more complete. Pulmonary exhalation should be carefully distinguished from the mucous matter secreted within the bronchiæ and trachea, and which is thrown up by a forcible expiration, and forms the matter of what we spit.

LXXXV. *Of asphyxia.* The term asphyxia, though merely indicating a want of pulse, is applied to any kind of apparent death occasioned by an external cause and suspending respiration, as submersion, strangulation, the diminution of oxygen in the air inhaled, &c. The only difference between real death, and asphyxia, is, that in this last state, the principle of life may yet be re-animated, whilst, in the other, it is completely extinct.

Asphyxia takes place in drowning, because the lungs, deprived of air, no longer impart to the blood which passes through them, the qualities essential to the support of life. The water does not find its way into these viscera: the spasmodic closing of the glottis, prevents its getting into the trachea and its branches. Yet there is found a small quantity in the bronchiæ, after drowning, always frothy, because air has mixed with it, in the struggles which precede asphyxia. If the body remain long under water, the spasmodic state of the glottis ceases, water passes into the trachea and fills the lungs. The anatomical examination of a drowned body, shews the lungs collapsed, and in the state of expiration; the right cavities of the heart, the venous trunks which terminate in them, and, generally, all the veins, are gorged with blood,* whilst the left cavities and the arteries are almost entirely empty. Life ceases in this kind of asphyxia, because the heart has sent to the different organs, and especially to the lungs, no blood that is not deficient in the qualities necessary to their action; and perhaps also, because the venous blood that is accumulated in the tissues, affects them by its oppressive and deadly influence. On that account, the best way of restoring the drowned to life, is to blow pure air into their lungs. This is done by means of bellows adapted to a canula introduced into the nostril; if a proper apparatus cannot be procured, one might blow with one's mouth into that of the drowned person, or into his nostrils, by means of a tube; but air so expired, having already undergone the process of respiration, contains a much smaller quantity of oxygen, and is much less fitted to excite the action of the heart. There remain several other less efficacious remedies, such as friction, bronchotomy glysters, fumigations and suppositories, stimulating errhines, and especially ammonia. Stimulants taken into the mouth and stomach, the application of fire, bleeding, the bath, electricity, and galvanism.

The redness and lividity of the face, in persons who are hanged, had led to the opinion that death, in such cases, was from apoplexy; but it appears that in the asphyxia from strangulation, as in that from drowning, death is caused by the interception of the air. To prove this, Gregory performed the following experiment; he opened the trachea of a dog, and passed a noose round his neck, below the wound. The animal, though hanged, continued to live and to breathe; the air entered and came out alternately, at the small opening. He died, when the constriction was applied below the wound. A respectable surgeon, who served in the Austrian army, assured me, that he had saved the life of a soldier, by performing upon him the operation of laryngotomy, a few hours before his execution.

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* Hence the dark and livid colour of the skin and conjunctiva. This last membrane is frequently injected with dark blood; the very delicate veins of the brain are considerably dilated, and this viscus is distended with venous blood.

Persons who are hanged may die, however, from dislocation of the cervical vertebræ, and from the injury done, at the same time, to the spinal marrow. Louis, it is well known, ascertained, that of the two executioners in Lyons and Paris, the one dispatched the criminals he executed, by dislocating the head at its articulation with the neck, while the other executioner destroyed them, by inducing asphyxia.

Of the different mephitic gases unfit for respiration, some appear to bring on asphyxia, merely by depriving the lungs of the vital air necessary to the support of life, while others evidently affect the organs and the blood which fills them, by their poisonous and deleterious influence.

One may mention among the former, carbonic acid; in the asphyxia occasioned by this gas, and which of all others, is the most frequent, the blood preserves its fluidity, the limbs their suppleness, and the body its natural warmth, or even a greater degree of warmth, for some hours after death; for, this kind of asphyxia occurring always in a very hot situation, the body, deprived of life, admits an excess of caloric, such as would have been resisted, if the vital power had not been suspended. However, in this asphyxia, as in the preceding, the lungs remain uninjured; the right cavities of the heart and the venous system, are gorged with a dark but fluid blood. In the asphyxia, on the other hand, that is occasioned by sulphureted or phosphureted hydrogen, &c. or by certain vapours whose nature is not well understood, and which escape from privies, or from vaults in which a number of dead bodies undergo putrefaction; there are frequently found in the lungs, dark and gangrenous marks, and death seems the effect of a poison which is the more active, as its particles, exceedingly divided and in a gazeous state, are more insinuating, and affect throughout its whole extent, the nervous and sensible surface of the lungs.

Inebriation seldom goes the length of bringing on asphyxia, it most commonly produces a stupor readily distinguished from the affection treated of in this article, by the perceptible, though obscure pulse, and by the motions of respiration, though these are rare and indistinct. On this account, M. Pinel, in his *Nosogra-*

phie philosophique,' has placed inebriation and the different kinds of asphyxia, in two separate genera of the class neuroses. It is conceivable, however, that the muscular irritability may be so far impaired by the use of spirituous liquors, that the heart and diaphragm might lose the power of contraction, which would bring on complete asphyxia.

The glottis, through which the atmospherical air passes, in its way to the lungs, is so small, that it may be readily obstructed, when the epiglottis rising at the moment of deglutition, the substance that is swallowed stops at the orifice of the larynx; a grape seed may produce this effect, and it was in this manner, we are told, that Anacreon, that lovely poet of the graces and of voluptuousness, came by his death. Gilbert, the poet, died in the same way, after a long and painful agony. A great eater, in the midst of a feast, went into an adjoining room, and did not return, to the great surprize of all the guests. He was found stretched on the floor, without any sign of life. Help, given by ignorant people, was of no use. On opening the body, a piece of mutton was found fixed in the larynx, and completely stopping the passage of the air.

Sometimes a child is born, and shews no signs of life. When it is probable, from the circumstances of the delivery, that there has been no organic injury decidedly mortal, it must be considered as a case of asphyxia, from weakness; and all means employed that are recommended in such cases, especially blowing in air into the lungs, by means of a tube introduced into the mouth or nostrils. It is thus, that the Prophet Elisha restored to life the son of the Shunammite, as we are informed, in the Second book of Kings, Chapter the fourth.

LXXXVI. *Of certain phenomena of respiration, as sighing, sobbing, yawning, sneezing, coughing; hiccup, laughing, &c.* When the imagination is strongly impressed with any object, when the vital functions are languid, the vital principle seems to forsake all the organs, to concentrate itself on those which partake most in the affection of the mind. When a lover, in the midst of an agreeable reverie, sighs deeply, and at intervals, a physiologist perceives in that expression of desire, nothing but a long and deep inspiration, which, by fully distending the lungs, enables the blood, collected in the right cavities of the heart, to flow readily into the left cavities of that organ. This deep inspiration, which is frequently accompanied by groans, becomes necessary, as the motions of respiration rendered progressively slower, are no longer sufficient to dilate the pulmonary tissue.

Sobbing differs from sighing, merely in this, that though the expiration is long, it is interrupted, that is, divided into distinct periods.

Yawning is effected in the same manner; it is the certain sign of ennui, a disagreeable affection, which, to use the expression of Brown, may be considered as debilitating or *asthenic.* The fatigued inspiratory muscles have some difficulty in dilating the chest, the contracted lungs are not easily penetrated by the blood which stagnates in the right cavities of the heart, and produces an uneasy sensation, which is put an end to, by a long and deep inspiration; the admission of a considerable quantity of air is facilitated by opening the mouth widely, by the separation of both jaws. One yawns at the approach of sleep, because the agents of inspiration, being gradually debilitated, require to be roused at intervals. One is, likewise, apt to yawn on waking, that the muscles of the chest may be set for respiration, which is always slower and deeper, during sleep. It is for the same reason, that all animals yawn on waking, that the muscles may be prepared for the contractions which the motions of respiration require. The crowing of the cock and the flapping of his wings seem to answer the same purpose. It is in consequence of the same necessity, that the numerous tribes of birds in our groves, on the rising of the sun, warble, and fill the air with harmonious sounds. A poet then fancies he hears the joyous hymn, by which the feathered throngs greet the return of the God of light.

While gaping lasts, the perception of sounds is less distinct, the air, as it enters the mouth, rushes along the eustachian tubes into the tympanum, and the membrane is acted upon in a different direction. The recollection of the relief attending the deep inspiration which constitutes gaping, the recollection of the grateful sensation which follows the oppression that was felt before, involuntarily lead us to repeat this act, whenever we see any one yawning.

Sneezing consists in a violent and forcible expiration, during which the air, expelled with considerable rapidity, strikes against the tortuous nasal passages and occasions a remarkable noise. The irritation of the pituitary membrane determines, by sympathy, this truly convulsive effort of the pectoral muscles, and particularly of the diaphragm.

Coughing bears a considerable resemblance to sneezing and differs from it, only in the shorter period of duration and the greater frequency of the expirations ; and as in sneezing, the air sweeps along the surface of the pituitary membrane and clears it of the mucus which may be lying upon it, so the air, when we cough, carries along with it the mucus contained in the bronchiæ, in the trachea and which we spit up. The violent cough, at the beginning of a pulmonary catarrh, the sneezing which attends coryza, show that the functions of the animal economy are not directed by an intelligent principle, for such an archæus could not mistake, in such a manner, the means of putting a stop to the disease, and would not call forth actions which, instead of removing the irritation and inflammation already existing, can only aggravate them.

Laughing is but a succession of very short and very frequent expirations. In hiccup, the air is forcibly inspired, enters the larynx with difficulty, on account of the spasmodic constriction of the glottis; it is then expelled rapidly, and striking against the sides of that aperture, occasions the particular noise attending it.

I shall, on another occasion, explain the mechanism of sucking, of panting, and of the efforts by which the muscles of the thorax fix the parietes of that cavity, so that it may serve as a fixed point for the other muscles of the trunk and of the limbs.

Respiration is besides employed in the formation of the voice, but the voice and the different modifications of which it is capable, will form the subject of a separate chapter.

LXXXVII. *Of cutaneous perspiration.* An abundant vapour is continually exhaling from the whole surface of the body, and is called the insensible perspiration, when in a state of gas in the air which holds it in solution, it then eludes our sight; it is called sweat, when in greater quantity and in a liquid form. Sweat differs, therefore, from insensible perspiration, only by the condition in which it appears, and it is sufficient for its production, that the air should be incapable of reducing it into vapour, whether from an increased secretion by the skin, or from the dampness and consequent diminished solvent powers of the atmosphere. The insensible perspiration is constantly escaping through the innumerable pores in the parietes of the minute arteries of the integuments; it oozes in the interstices of the scales of the skin; the air which immediately surrounds our body, becomes saturated with it, and carries it off, as soon as it is renewed. There is the greatest resemblance between the cutaneous perspiration and the pulmonary exhalation; both are mere arterial exhalations, and the mucous membrane, which lines the canals along which the air is transmitted, is a mere prolongation of the skin into those organs and into the digestive tube. The surface from which the cutaneous perspiration is exhaled, is not quite so considerable as that from which the pulmonary exhalation arises, since it is reckoned at only fifteen square feet, in a man of middle size. These two secretions are supplementary to each other; the increase of the one is generally attended with a sensible diminution of the other; lastly, the mucous membrane of the intestinal canal, besides secreting mucus, exhales likewise a fluid which increases much in quantity, when the cutaneous perspiration is languid, as is proved by the serous diarrheas so frequently occasioned by a suppressed perspiration. It must be owned, however, that notwithstanding those analogies of structure and function, in the skin and mucous membranes, there exists perhaps a still more intimate connexion between its action and that of the organs which secrete the urine; it has always been observed, that when this last fluid is scanty, there is a greater cutaneous perspiration, and *vice versâ.*

If we examine, with a microscrope, the naked body, exposed during summer to the rays of a burning sun, it appears surrounded with a cloud of steam, which becomes invisible, at a little distance from the surface. And if the body is placed before a white wall, it is easy to distinguish the shadow of that emanation. We may, likewise, satisfy ourselves of the existence of the cutaneous perspiration, by the following experiment: hold the tip of the finger, at the distance of the twelfth part of an inch from a looking glass, or any other highly polished surface, its surface will soon be dimmed by a vapour condensed in very small drops, which disappear on removing the finger. One may, in this manner, ascertain that the cutaneous perspiration varies in quantity, in different parts of the surface of the body, for, on placing the back of the hand before a looking glass, the latter will be covered by no vapour.

No function of the animal economy has been the subject of more investigation, nor has any excited the attention of more accurate and indefatigable physicians, than the secretion now under consideration. From the time of Sanctorius, who, in the beginning of the seventeenth century, published in his immortal work "*Medicina statica*" the result of experiments carried on, for thirty years, with a patience which very few will imitate, to that of Lavoisier, who jointly with Séguin, aided by the resources of the improved state of chemistry, instituted an examination of the insensible perspiration, we find engaged in this enquiry, Dodart, who in 1668 communicated to the Academy of Sciences, which had been founded but a short time, the result of his observations at Paris, under a climate different from that of Venice, where Sanctorius lived:—Keill, Robinson, and Rye who repeated the same experiments in England and Ireland:—Linnings who performed his in South Carolina; and several physiologists of no less merit, as Gorter, Hartmann, Arbuthnot, Takenius, Winslow, Haller, &c. who all aimed at ascertaining, with more precision than had been done by Sanctorius, the variations in the cutaneous perspiration, according to the climate, the season of the year, the age, the sex, the state of health or disease, the hour of the day, and the quantity of the other secretions.

According to Sanctorius, of eight pounds of solid and liquid aliments taken in twenty-four hours, five were carried off by the perspiration, and only three in excrement and urine. Haller conceives this calculation to be exaggerated; Dodart, however, carried it still further, and maintained that the relation of the perspiration to the solid excrements, was as seven to one.

In France and in temperate climates, the quantity of the cutaneous perspiration, and of the urine, is nearly the same; it may be estimated at between two and four pounds in the twenty-four hours. We perspire most in summer, and void most urine in winter. The perspiration, like every other secretion, is in smaller quantity during sleep, than while we are awake; in old age than during infancy, in weak persons, and in damp weather, than under the opposite circumstances.

The perspiration may be said to be in a compound ratio of the force with which the heart propels the blood into the minute capillary arteries, of the vital energy of the cutaneous organ, and of the solvent powers of the atmosphere. The strongest and most robust men perspire most; some parts of the skin perspire more than others, as the palms of the hands, the soles of the feet, the arm pits, &c. When the air is warm, dry, and frequently renewed, cutaneous perspiration is greater, and the necessity of taking liquid aliment is more urgent, and more frequently experienced; in summer, as every body knows, a profuse perspiration is brought on by passing from the heat of the sun into the shade; and, on no occasion, is a copious sweat more easily brought on, than by taking exercise in summer, when, on the approach of a storm, the atmosphere, containing a considerable quantity of vapours, and warm from the rays of the sun which shows itself, now and then, surrounded by the clouds, is little capable of dissolving the insensible perspiration.

The skin may be covered with sweat, without any increase of the cutaneous perspiration; this may happen from dampness in the air, or from its being imperfectly renewed. It must be owned, however, that sweating is more frequently occasioned by an increase of the insensible perspiration, and that the warmth of the bed which excites it, acts by increasing the power of the organs of circulation and the energy of the cutaneous system. The body is weakened by sweating, which is seldom the case with the insensible perspiration. A profuse sweat is attended with a very speedy exhaustion; thus, in hectic fever, in the *suette (sudor anglicus)* and other affections, equally dangerous, it is the cause of a wasting almost universally fatal.

The matter of the insensible perspiration and of the sweat, is, in great measure, aqueous. Like the urine, it holds in solution several salts, also the volatilized recrementitious matter of animal substances, sometimes even acids, as in the case in which Berthollet detected the phosphoric acid in children affected with worms, in pregnant women, in nurses, from whom there exhales an odour manifestly acid. It may contain ammonia, and, on certain occasions, the smell enables us to discover that alkali, in the sweat or perspiration.

The air which constantly surrounds our body, does not merely dissolve the aqueous vapour which arises from it, but several physiologists, very reasonably conjecture, that the oxygen of the atmosphere may combine with the carbon of the blood brought to the skin by the numerous vessels which are sent to it, and likewise with the gelatine forming the substance of the rete mucosum of Malpighi.

The experiments of Jurine, of Tingry, and of several other naturalists, show that carbonic acid is constantly formed on the surface of the skin, so that the skin may be considered as a supplementary organ to that of respiration; and in that point of view, one may compare to it, the mucous membranes which are in contact with the atmospherical air in the nasal fossæ, and in the intestinal canal which they line.

The cutaneous perspiration is, likewise, as was before mentioned, a powerful means of cooling the body, and of keeping it while living, in an uniform temperature. The water which is exhaled from the whole surface of the body, carries off from it, in passing into vapour, a considerable quantity of caloric; and it is observed that every thing which increases the production of caloric, gives rise to a proportionate increase of the cutaneous perspiration and of the pulmonary exhalation, so that a constant equilibrium being kept up between its production and escape, the animal warmth always remains nearly the same.

To conclude, the extremities of the nerves of our organs of sensation, are all moistened by a fluid varying in quantity, and which maintains them in a softened state, favourable to the exercise of their functions. It was likewise necessary, that the membrane in which the sense of touch resides, should be habitually kept moist by a fluid that should penetrate it throughout; this use of the insensible perspiration is not less important than the preceding, on which physiologists have bestowed most attention.

CHAPTER V.

OF THE SECRETIONS.

LXXXVIII. *Of the animal fluids.* The animal fluids were formerly divided into *recrementitious*, *excrementitious*, and *excremento-recrementitious;* this division, founded on the uses to which the fluids are subservient, is preferable to any that has since been adopted, and in which they are ranked according to their nature.

The first class remain in the body and are employed in its nutrition and growth; such as the chyle, the blood, the serosity which lubricates the surface of the pleura, of the peritoneum, and of the other membranes of the same kind. The second kind are ejected from our body, and cannot remain long within it, without danger; such as the urine, the matter of insensible perspiration and of sweat. Lastly, those of the third class partake of the nature the two preceding, and are, in part, rejected, while another part is retained and employed in the support and growth of the organ; this is the case with the saliva, the bile, the mucus of the intestines, &c. If one affected to be very minutely scrupulous, one might consider all the animal fluids as recremento-excrementitious. The chyle and the blood, which are so very nutritious, contain an abundance of heterogeneous and excrementitious parts; the urine which of all our fluids is that which may, with most propriety, be termed such, contains, likewise, aqueous parts, which, while it remains in the bladder, the lymphatics absorb and carry into the mass of the fluids.

Of all the modern divisions, Fourcroy's is the best; Vicq-d'-Azir acknowledged its superiority over that proposed by Haller, in his Physiology. Fourcroy admits six classes of fluids: 1st, those which hold salts in solution, as the sweat and urine; he gives the name of *saline* to such fluids: 2nd, inflammable *oily* fluids, all possessing a certain degree of consistence and concrescibility, as fat, and the cerumen of the ears, &c.: 3d, the *saponaceous* fluids, as the bile and the milk: 4th, the *mucous* fluids, as those which lubricate the internal coat of the intestinal canal: 5th, the *albuminous* fluids, among which one may rank the serum of the blood. The *fibrinous* fluids, containing fibrina, as the fluid last mentioned.

In proportion as we advance in our knowledge of animal chemistry, the defects of these divisions become more and more evident. In short, the animal fluids are so compound, that there is not one which does not, at once, belong to several of these classes, and whose prevailing element is not sometimes exceeded in quantity, by materials which commonly form but a small part of them.

LXXXIX. The blood is the reservoir and the common source of the fluids; these do not exist in the blood, with the qualities which characterize them, unless, after having been previously formed by the secretory organs, they have been absorbed by the lymphatics and conveyed, with the chyle and lymph, into the circulatory system. Let us shortly attend to its nature, although this belongs more especially to the department of chemistry. The blood is red in man and in all warm-blooded animals, and even in some whose temperature is not very different from that of the atmosphere, as in fishes and reptiles. This colour, of a deeper or lighter shade, according as the blood is drawn from an artery or a vein, varies in its degree of intensity, according to the state of health or weakness. It is of a deep red in strong and active persons, pale and colourless in dropsical patients, and whenever the health is weak. By its colour, one may judge of all its other qualities. Its viscidity is greater, its saline taste more marked, its peculiar smell stronger, when its colour is deep. This colour is produced by a prodigious number of globular molecules, which move and float in an aqueous and very liquid fluid. When the blood is pale, the number of these molecules diminishes, they seem to be dissolved in cachexiæ.

The microscope, which affords the only method of perceiving them, does not enable one to determine their bulk and their figure. Leeuwenhoek, who brought forward the idea of their being so minute, by his calculation that they were one million'th part of an inch in size, thought them spherical; Hewson says they are annular and have an opening in their centre. Others compare them to a flatened lentil, with a dark spot in the middle. They are solid, and formed by a nucleus or red point covered over by a membranous vesicle, which appears to be readily formed and destroyed.

XC. The blood, when no longer in the course of the circulation, and on being received into a vessel, parts with its caloric and exhales, at the same time, a powerful smell, a gas to which, according to some physiologists (Moscati, Rosa, &c.), it owes its vital properties, and the absence of which is attended with a loss of its vitality; so that its analysis cannot furnish facts applicable to the explanation of the phenomena of health and disease. This odour, extremely strong in carnivorous animals, is very distinguishable in man, especially in arterial blood. I remember retaining it, a whole day, in my throat, after removing the dressings, and suppressing a hemorrhage, occasioned by a relaxation of the ligatures, a week after the operation for popliteal aneurism. Unless by agitation it is prevented from coagulating, as it cools, its consistence increases, and, on being laid by, it separates into two very different parts, the one aqueous, more or less red, heavier than common water, and evidently saltish; this is called the serum, consisting of water, in which are dissolved albumen, gelatine, soda, phosphates, and muriates of soda. Nitrate of potash, and muriate of lime.

Serum, though bearing some analogy to the albumen of egg, differs from it, in forming, on coagulating, a less solid and less homogeneous mass. The albumen is evidently mixed with a portion of transparent gelatine, not coagulable by heat. Albumen has so great an attraction for oxygen, that it is fair to presume, that the serum absorbs oxygen and combines with it, through the very thin parietes of the air cells of the lungs, and that it gives to arterial blood that spumous appearance which is one of its distinguishing characters. This oxidizement, and the fixation of the caloric which accompanies it, equally increase its consistence. It does not, however, coagulate; because it is kept in perpetual motion by the circulatory action, and is diluted by a sufficient quantity of water; because the animal temperature, which never exceeds thirty-two or thirty-four degrees, cannot give a solid form to albumen, which coagulates only at fifty degrees of Réaumur's thermometer; and lastly, because as serum contains a certain quantity of uncombined soda, which enables it to turn green, vegetable blues, this alkali concurs in keeping the albumen in a dissolved state, which it renders fluid, when it has been coagulated by the acids, by heat, or by alcohol.

Amid the serum, and on its surface, there floats a red cake, spungy, and solid (*insula rubra*) which, by repeated washing, may be separated into two very distinct parts. The one is the cruor or the colouring matter which mixes with the water; it is a more highly oxygenated and more concrescible albumen than that of the serum; it holds in solution soda, as well as phosphate of iron, with an excess of iron.

The other is a solid and fibrous substance, which, after being repeatedly washed has the appearance of felt, the filaments of which cross each other, are extensible and very elastic. This third part of the blood is called *fibrina*, it is very similar in its nature to muscular fibre, and like it, gives out, on distillation, a considerable quantity of carbonate of ammonia. Fibrina does not exist in the blood in a solid form, but in a state of solution and combined with the other constituent parts of the fluid, as is indicated by the appropriate expression of liquid flesh (*chair coulante*) first used by Bordeu, in speaking of the blood.

XCI. If the blood be exposed to the action of fire, if it be calcined and reduced to powder, and if this pulverized substance be exposed to a magnet, the presence of iron will be manifestly seen by the magnetic attraction. Authors do not agree in their accounts of the quantity of iron contained in the blood. Menghini says, there is one part in the hundred; others that it is in the proportion of 1 to 303; so that it is propable, that this constituent principle of the blood, like all the materials of our fluids, may vary in quantity, according to different circumstances.

Blumenbach justly observes, that iron is found only in calcined blood; that none is to be found if it be slowly dried. This peculiarity is no longer surprising, since M. Fourcroy has shown that iron existed in the blood, in combination with the phosphoric acid, and formed with that acid a phosphate of iron, with an excess of its base. This salt becomes decomposed by calcination, the iron is set free and is acted upon by the magnet. Physiologists attribute the colour of the blood, to the presence of the oxide of iron in that fluid.

It is, at present, the received opinion, that the red colour of the blood is owing to the presence of phosphate of iron, which being conveyed, of a white colour, into the blood, along with the chyle, meets with the pure soda, by which it is dissolved, and from which it receives its colour; the colour of the blood is, likewise, owing to the oxidizement of the metallic portion, which is in very considerable quantity in that salt. This solution of the phosphate of iron by soda, the oxidizement of the excess of iron, and the absorption of oxygen by albumen, constitute, in an especial manner, *hematosis* or *sanguification*, which is principally carried on in the lungs.

The respective proportion of the three parts into which the blood separates spontaneously, varies considerably. The serum constitutes about one half or three fourths of the fluid; the colouring matter and fibrina are in inverse ratio of the serum, and it is observed, that the more brilliant and red the colour of the blood, the greater the proportion of the fibrous part. The pale, aqueous, and colourless blood of a dropsical patient contains very little fibrina. In putrid or adynamic fever in which bleeding, as is universally known, is improper, I have sometimes seen the blood containing but a small portion of fibrina, and very slow of coagulating; its texture seemed to suffer from the affection under which the muscular organs were evidently labouring. In inflammatory diseases, on the contrary, the plastic power of the blood is augmented; the fibrina is in greater quantity, even the albumen coagulates spontaneously and forms a crust above the serum, which is always in smaller quantity.

XCII. *Of the changes on the blood.* The fluids not only undergo changes in their composition, in their qualities, and nature, when the action of the solids is itself altered, but even the absorbent system may introduce, into the mass of our fluids, heterogeneous principles, evidently the cause of several diseases. In this manner, all contagions spread, the virus of small pox, of syphilis, of the plague, &c. Thus, in time, the habitual use of the same aliment produces in our fluids a *crasis* or peculiar constitution which has, on organized solids, an influence acting even on the mind.

A purely vegetable diet conveys into the blood, according to Pythagoras, bland and mild principles; this fluid excites the organs, in a moderate degree, and this check over the physical excitement, facilitates the observance of the laws of temperance, the original source of all virtues. These observations of ancient philosophy, on the influence of regimen, have, doubtless, led their authors to exaggerated inferences, but they should not be considered as altogether unsupported. The carnivorous species are marked by their strength, their courage, and their ferocity; savages who live by hunting, and who feed on raw, bloody, and palpitating flesh, are the most ferocious of men; and, in our own country, in the midst of those scenes of horror which we have witnessed, and from which we have suffered, it was observed, that butchers were foremost in the massacres, and in all the acts of atrocity and barbarity. I know that this fact, which was uniformly noticed, has been explained by saying, that the habit of slaying animals, had familiarized them to shed human blood. But though I do not deny the existence of this moral cause, which certainly operates, I think I may add to it, as a physical cause, the daily and plentiful use of animal food, the breathing an air filled with emanations of the same kind, which they inhale, and which contribute to their embonpoint, which is sometimes excessive.

As the plasticity and concresibility of the blood are diminished in asthenic diseases or of debility, as putrid fevers and scurvy, two causes may be assigned for the hemorrhages which come on in those diseases, viz.: the relaxed state of the vessels and the dissolution of the blood. In scurvy, the tissue of the capillaries is relaxed, its meshes enlarged, red blood passes into them, transudes through their parietes, and forms scorbutic spots. I have sometimes seen those ecchymoses or sanguineous cutaneous transudations, extend under the skin of the whole of one lower extremity. Petechiæ, in putrid fever, are formed in the same manner, and depend, likewise, on the relaxation of the minute vessels, and on the greater fluidity of the blood, whose molecules are less coherent, and more readily separated from each other.

In the summer of the year 1801, I amputated the arm of an old man of sixty, on account of a corroding and varicose ulcer, which for thirty years had occupied a part of the forearm, and extended to the elbow. All who were present at this operation, observed that the blood which flowed from the arteries, was not nearly so red as that from the arteries of a young man, whose thigh had just been taken off, on account of a scrophulous caries of the leg; that the venous blood was entirely dissolved, purple, and similar to a weak dye of logwood. This blood did not coagulate, like that of the young man, it became fluid and was converted into a serum containing a few colourless clots.

Those who have endeavoured to find, in the changes undergone by the blood and the other fluids, the cause of all diseases, have fallen into as serious blunders as the determined solidists, who maintain that all diseases arise from a deranged condition of the solids, and that every change in the condition of the fluids is a consequence of that derangement. The believers in the humoral pathology, have certainly gone too far; they have admitted that the animal fluids might be *acid*, *alkalescent*, *acrimonious*, while we have no proof whatever that they ever do undergo such changes. The solidists have, likewise, gone much beyond the truth, in saying, that every primitive change in the condition of the fluids is imaginary, and that the doctrine of humoral pathology is without foundation. Stahl relates* that the blood of a young woman, who was bled during a fit of epilepsy, was absolutely coagulated, as if that fluid had partaken in the rigidity affecting the muscular organs. Some authors say they have met with the same appearance; I have, however, never been able to discover any sensible difference, between the blood of an epileptic patient and of any other person of the same constitution, of the same age, and living on the same regimen; and it should be considered, that to make a just comparison of our fluids, it is necessary that every thing should be alike in the persons from whom they are taken, with the exception of the difference of which we are to judge. In fact, the blood has not the same appearance, and does not coagulate, in the same manner, when taken from a child, a woman, or an old man; from a man who lives abstemiously, or from one who lives on a full diet.

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* *Theoria medica vera*, page 678.

After enumerating the changes which the blood undergoes, one might speak of those which affect the fluids that are formed from it, one might attend to the greenish, leek colour, and sometimes even darkish appearance of the bile, which is not always of the same degree of bitterness; the limpid state of the urine, which is voided colourless, without smell or flavour, after a fright, or during the convulsive fits of hysterical women; the fetid smell and the viscidity of the saliva, when the salivary glands are under mercurial influence; the milky state of the serum which lubricates the parietes of the abdomen and of the viscera which it contains, after inflammation of the peritoneum; changes which, almost universally, depend on a derangement of action in the secretory organ, and sometimes, likewise, on the general condition of the fluids; for, a gland cannot secrete a fluid endowed with the qualities which peculiarly belong to it, unless the blood furnish it with the materials of secretion, and unless it be in a state to bring about a due combination of their particles. When we come to the article of accidental secretions, we shall speak of some of those disorders of the fluids, depending on a depraved condition of the secretory organs.

XCIII. *On the transfusion of blood.* In the midst of the disputes to which the discovery of the circulation gave rise, some physicians conceived the idea of renovating completely the whole mass of the fluids, in persons in whom they might be vitiated; by filling their vessels with the blood of an animal or of a person in good health. Richard Lower, known by his work on the heart, first practised it on dogs, in 1665. Two years afterwards, transfusion was performed at Paris on men, it excited the greatest expectations: it was thought, that by this process, called transfusing surgery (*chirurgie transfusoire*), all remedies would be superseded, that henceforth, to cure the most serious and inveterate diseases, it would be necessary merely to transfuse the blood of a strong and healthy man into the veins of the diseased; nay, they went so far as actually to imagine they might realize the fabulous fountain of *Jouvence;* they expected no less, than to restore youthful vigour to the old, by infusing into them the blood of the young, and thus to perpetuate life. All these brilliant chimeras soon vanished, some underwent the experiment, without any remarkable effects from it, others were affected with the most violent delirium; a lad of fifteen lost his senses, after suffering two months from the most violent fever. The legislative authority at last interfered, and prohibited those dangerous experiments.

The experiments on the subject of the tranfusion of blood were repeated, but without success, at the Academy of Sciences. Perrault opposed this new method, and showed that it was very difficult for one animal to exist on the blood of another, that this fluid, though apparently the same in animals of the same age, was as different from it as the features of their face, their temper, &c. that an extraneous fluid was thus introduced, which conveying to the organs an irritation to which they were not accustomed, must disorder their action, in various ways; that if, as an objection to what he had said, they should bring forward what takes place in grafting, in which the sap of one tree nourishes another of a different kind, he would answer, that vegetation does not depend on so complicated, nor on so delicate a mechanism, as the nutrition of animals; that a hut may be formed of all kinds of stones taken at random, but that to build a palace, stones must be designedly shaped for the purpose, so that a stone destined for an arch, will not do for a wall, nor even for another arch*.

It would be easy, by means of a curved tube, to transfuse the arterial blood of an animal, from a wound in its carotid artery, into the saphena vein of a man, into the internal jugular, or into some of the cutaneous veins of the fore arm; but it is to be presumed, from experiments on living animals, that it would be very difficult to transfuse blood into the arteries, as these vessels, filled with blood, during life, do not yield to a greater distention. The capillaries, in which the arteries terminate, become corrugated and refuse to transmit a fluid which does not act upon them, according to their wonted sensibility. Such was the result of the experiments of Professor Buniva; he observed, in a living calf, that the vessels did not transmit freely the fluid which was forced into them, till the instant when the animal was killed, by dividing the upper part of the spinal marrow. Attempts have been made to turn to useful purposes these experiments on transfusion, by limiting the process to the injecting of medicinal substances into the veins. It is singular, that the moment a fluid is injected into the veins of an ani-

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[illegible] * Academie royale des Sciences, 1667, page 37.

mal, it endeavours to perform motions of deglutition, as if the substance had been taken in at the mouth. All these attemps have been too few in number, and are not sufficiently authenticated to justify their application to the human subject. But there is every reason to believe, that, even with the utmost care, the life of those who should submit to them, would be endangered; so that it is at once humane and prudent to abstain from them.

XCIV. *Of the secretions.* It has been said, in too general a way, that the organs receive from the blood conveyed to them by the arteries, the materials of the fluids which they separate from it. We have seen, that the liver is a remarkable exception to this general rule; the same observation seems, likewise, applicable to the mammæ; they appear to receive the elements of their milky secretion, from the lymphatics, which are so very numerous in their structure.

One is, therefore, justified in saying, that the elements of our fluids may be furnished by vessels of every kind, to the organs in which such fluids may be elaborated. The term *secretion*, whatever its etymology may be, denotes that function by which an organ separates from the blood, the materials of a substance which does not exist in that fluid, with its characteristic qualities. By the term secretion, one should not, therefore, understand the mere separation of a fluid existing, before the action of the organ by which it is prepared.

XCV. The differences between the secreted fluids, are evidently connected with those of the organs employed in their formation. Thus, the arterial exhalation which takes place, throughout the whole extent of the internal surfaces, maintains their contiguity, throws out an albuminous serosity which is merely the serum of the blood, slightly changed, by the feeble action of a very simple organization. The analysis of the fluid of dropsy, which is merely the serosity constantly transuding from the surface of the serous membranes, as the pleura and peritoneum, shows, that it bears the strongest resemblance to the serum of the blood, and that it differs from it, only in the varying proportions of albumen and of the different salts which it holds in solution.

This first kind of secretion, this perspiratory transudation, would seem to be a mere filtration, through the pores of the arteries, of a fluid already formed in the blood. There is, however, besides, an inherent action in the membranes whose surface it continually lubricates. If it were not for this action, the serum would remain united to the other constituent parts of the fluid, which is in too much motion, and at too high a temperature, to allow of a spontaneous separation. The term exhalation, which is applied to this secretion, gives an incorrect idea of it, for, exhalation, which is a purely physical phenomenon, and requiring the presence of air to dissolve the fluid that is exhaling, cannot take place from surfaces that are in absolute contact, and between which there is no interval. The character of this mode of secretion, is the absence of any intermediate substance, between the vasa afferentia and the excretory ducts; the minute arteries and veins which enter into the structure of the membranes being, at once, vasa afferentia and excretory ducts. The fluid secreted by the serous membranes, though bearing a considerable analogy to the serum of the blood, differs from it, however, by being animalized in a greater degree. The most important function of these organs is, therefore, that they concur in the common process of assimilation; the office which has been long assigned to them of facilitating the motion of the organs which they envelop, by lubricating their surface, will appear to be of very secondary importance, if it be considered, that respiration is not impeded by adhesions between the lungs and the pleura, and that, besides, the brain, which when the cranium is whole, is completely motionless, is entirely surrounded by a serous membrane.

XCVI. Next in order to the serous transudation, which requires a very simple organization, comes the secretion which takes place in the cryptæ, in the glandular follicles and in the mucous lacunæ. Each of these small glands, contained within the membranes lining the digestive canal, the air tubes, and the urinary passages, and the collection of which forms the amygdalæ, the arytenoid glands, &c. may be compared to a small bottle with a round bottom, and a very short neck; the membranous parietes of these vesicular cryptæ receive a considerable number of vessels and nerves. The peculiar action of the parietes of these different parts, determines the secretion of the mucus furnished by those glands. These mucous fluids, less liquid and more viscid than the serosity which is the product of the first mode of secretion, contain more albumen and a greater number of salts, differ still more from the serum of the blood, and are of a more excrementitious nature.

The bottom of these utricular glandulæ, is turned towards the parts to which the mucous membranes adhere; their mouth, or neck, opens on the surface at which those membranes are in contact. These kinds of excretory ducts, wider, or narrower, and always very short, sometimes unite, run into each other, and open within the cavities. These common orifices, at which several mucous glands empty themselves, are easily seen on the amygdalæ, towards the mucous lacunæ of the rectum and of the urethra, at the base of the tongue, &c. The albuminous fluid, which is poured within those glandular cryptæ, remains some time within the cavity, becomes thicker from the absorption of its more fluid parts; for, there are, likewise, lymphatics within the texture of their parietes. When the surfaces, on which they are situated, require to be moistened, this small pouch contracts, and throws up the fluid with which it is filled. The secretion and excretion are promoted by the irritation which the presence of the air, of the aliment, or of the urine occasions, by the compression exerted by those substances, and lastly, by the peristaltic contractions of the muscular planes to which the mucous membranes adhere, throughout the whole extent of the digestive tube.

XCVII. Those fluids which differ much from the blood, require for their secretion, organs of a more complicated nature; such organs are called *conglomerate* glands, to distinguish them from the lymphatic glands, which have been termed *conglobate.* Those glands constitute the viscera, and are formed by a number of nerves and vessels of all kinds, arranged in fasciculi and united by cellular membrane. A membrane peculiar to the organs, or supplied by those which line the cavities in which they are contained, covers their outer part, and insulates them from the neighbouring organs.

The intimate arrangement of the different parts which form the secretory glands, the disposition of the arteries, of the veins and nerves, and the manner in which the lymphatics and excretory ducts arise from them, have given rise to endless discussions, and formed the basis of former physiological theories. What follows may be considered as a correct abstract of what is known on the subject.

The respective arrangement of the similar parts *(parties similaires*)* which enter into the structure of the glands and which form their proper substance, or parenchyma†, is different in each of them; this explains their differences, in the double relation of their properties and their uses. The arteries are not, as Ruysch thought, immediately continuous with the excretory ducts, nor are there intermediate glands between those vessels, as Malpighi conceived. It seems more probable, that each gland has its own peculiar cellular or parenchymatous tissue, in the areolæ of which, the arteries pour the materials of the fluid which the gland prepares, in virtue of a power which is inherent to it, and which is its distinguishing character. The lymphatics and the excretory ducts arise from the parietes of those cells; and these two kinds of vessels absorb; the one set, the secreted fluid which they carry to the reservoirs in which it accumulates, while the other set take up that part of the fluid, on which the organ has not completed its action; in other words, the residue of secretion.

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* By, *parties similaires*, the author means the simple elementary tissues.—See the preliminary discourse, page 17.

† Do the different appearances of the substance of glandular bodies, depend on

XCVIII. *Of accidental secretions.* If one wished to extend the idea attached to the term secretion, one might say, that every thing, in the living economy, is performed by means of the secretions. What is digestion, but the separation or secretion of the chylous or nutritive parts of aliments, from their fæcal or excrementitious portion? Do not the absorbents concur in this secretion; may they not be considered as the excretory ducts of the digestive organ which acts on the aliment, in the same manner as a secretory gland acts on the blood that contains the materials of the fluid to be elaborated. Respiration, as we have already seen, is but a double secretion which the lungs perform, on the one hand, of the oxygen contained in the atmospherical air, and on the other hand, of the hydrogen and carbon, of the water, and of the other heterogeneous principles contained in venous blood; and, as will be shewn in the ensuing chapter, nutrition is but a peculiar mode of secretion which is different in every organ. It is, therefore, only after a series of very delicate and very complicated separations and analyses, that the organs are enabled to make extraneous substances undergo such a change of composition, as to render them fit for their growth and reparation.

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the different manner in which the similar parts cross each other, and on their different proportions in every gland; or do these differences of colour, of density, by means of which we, so readily, distinguish the substance of the liver from that of the salivary glands, depend on the existence of a peculiar tissue in each organ? This question cannot be answered, in the present state of anatomy. The opinion, however, which supposes the different nature of the glands to depend on the different proportions of those constituent parts, in each of them, appears the most probable.

There is every reason to believe, that the phenomena of sensation and of motion, by means of which man keeps up, with surrounding objects, the relations necessary to his existence, are the result of the secretions of which the blood furnishes the materials prepared by the brain, by the nerves, by the muscles, &c. A plant separates from the earth, in which its roots are buried, the juices which it requires; these juices constitute the sap, which, after being filtered through a multitude of canals, supplies the different secretions whose products are leaves, blossoms and fruits, with gums, essential oils, and acids. All organized bodies are, therefore, so many laboratories, in which numerous instruments spontaneously perform various compositions, decompositions, syntheses, analyses, which may be considered as so many secretions from the common fluid.

If we confine ourselves in our view of the subject, and limit our attention to man, the principal and almost the sole object of our study, we shall see that the different secretions that may take place in him, are extremely numerous and varied, and that a change in the condition of one of his organs, is sufficient to enable it to secrete a new fluid. Hence inflammation in any gland, is sufficient to alter the secretion of the organ that is affected. A portion of adipose tissue, on being affected with inflammation, shall secrete, instead of fat, a whitish fluid known by the name of pus. The pituitary membrane, when inflamed, furnishes a mucus more fluid and more abundant, and which, by degrees, returns to its natural state, in proportion as the coryza goes off; the serous membranes, as the pleura and the peritoneum, will allow a greater quantity of serum of a more albuminous quality, sometimes even coagulable lymph, to exude; at other times, inflammation causes an adhesion of their contiguous surfaces, and as the inflammatory state varies in intensity, the accidental secretion will likewise vary as to its qualities; thus, the phlegmonous inflammation which should furnish, on terminating in suppuration, a whitish fluid, thick, consistent, and almost without smell, will give out, if the process is not sufficiently active, a serous pus, colourless, and without consistence, &c. For the same reason, the blood vessels of the uterus pour out, in some women, a dark coloured blood, while in others, they give out a mere serosity, very slightly, if at all, tinged with blood.

The menstrual discharge, in women, is the product of a real secretion of the arterial capillaries of the uterus, in the same manner as those vessels in the pituitary membrane, the membrane which lines the bronchiæ, the stomach, the intestines, the bladder, &c. pour out blood abundantly, or allow its transudation, when irritation is determined to those parts; in hemorrhage from the nose, in bleeding from the lungs, or from the stomach, when the vessels are not ruptured by external violence. Apoplexy itself, whether sanguineous or serous, may, in several instances, be ranked among those secretory evacuations, the quality of which varies, according to the energy of the capilliaries which produce it. On opening dead bodies, one frequently meets with a collection of blood in the ventricles of the brain, in persons who have died from apoplexy, yet the most careful examination does not enable one to detect the slightest laceration or rupture in the veins or in the arteries within the skull.

The nerves, of which there is always a certain number in the structure of the secretory organs, and which are principally branches of the great symphathetic* nerves, terminating in various ways, in their substance, give to each of them a peculiar sensibility, by means of which they discover in the blood which the vessels bring to them, the materials of the fluid which they are destined to secrete, and these they appropriate to themselves by a real selection. Besides, the nerves communicate to them a peculiar mode of activity, the exercise of which makes those separated elements undergo a peculiar composition, and bestows on the fluid which is the product of it, specific qualities always bearing a certain relation to the mode of action of which it is the result. Thus, the liver seizes the materials of the bile contained in the blood of the vena portæ, elaborates, combines those materials, and converts them into bile, an animal fluid, distinguishable by peculiar characteristic properties subject to certain variations, according as the blood contains, in different proportions, the elements of which it is formed; according as the gland is more or less disposed to retain them, and to blend them together. The qualities of the bile depending on a concurrence of all these circumstances, must present as many differences as the blood which contains its elements, and the liver may present varieties, with regard to the composition of the former and to the activity of the latter. Hence the many changes in the qualities of the fluid, the slightest of which, not affecting the health, escape observation, while those changes which are greater and which disorder the natural order of the functions, shew themselves in diseases of which they may be considered as the effect, and at other times, as the cause. These changes in the condition of the bile (and what is now said applies to almost all the secretions of the animal economy), these changes are never carried so far as to make the bile lose all its distinguishing characters, it never takes on the qualities belonging to another fluid, it never resembles semen, urine, or saliva.

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* They are likewise given off, in great number, from the cerebral; thus, the salivary glands receive from the seventh pair, from the maxillary nerve, from the fifth pair and from the cervical nerves, a number of nerves that will appear very great, if the bulk of those glands is considered.

The secretory glands do not carry on an uninterrupted action; almost all of them are subject to alternate action and repose; all, as Bordeu observed, sleep or waken, when irritation affects them or their neighbouring parts, and determines their immediate or symphathetic action. Thus, the saliva is more plentifully secreted during mastication; the gastric juice is poured within the stomach, only while digestion is going on; when the stomach is emptied of food, the secretion ceases, and is renewed, when the presence of food again excites a sufficient degree of irritation. The bile flows more abundantly, and the gall bladder frees itself of that which it contains, while the duodenum is filled by the chymous mass.

When a secretory organ is in action, it determines the motion of the parts in its vicinity, or, as Bordeu expresses it, within its atmosphere. A part is said to belong to the department of a certain gland, when it partakes in the motion affecting the latter, during the process of secretion, or when it is employed in functions subservient to that of the gland; these departments are of different extent, according to the importance of the action of the gland. Thus, one may say that the spleen and most of the viscera of the abdomen are of the department of the liver since they receive from it, the blood on which they are to act. The liver is also comprized in the sphere of activity of the duodenum, since the distention of that intestine irritates it, determines a more copious flow of its fluids, and a more abundant secretion of bile.

C. The blood which is sent to a secretory gland, before reaching it, undergoes preparatory changes, which dispose it to furnish the materials of the fluid which is to be separated from it. We have seen, in treating of digestion, how the blood which the vena portæ sends to the liver, is fit for the secretion of bile. There can be no doubt, that the portion of blood which is carried to the testicles, by the long, slender, and tortuous spermatic arteries, undergoes changes which bring it nearer to the seminal fluid.

The rapidity with which the blood flows into an organ, the length, the diameter, the direction, the angles of its vessels, the arrangement of their extreme ramifications, which may be stellated, as in the liver, in fasciculi, as in the spleen, convoluted, as in the testicles, &c. are circumstances which should be taken into account in the study of each secretion, since all have some influence on the nature of the fluid secreted, and on the manner in which the secretion is effected.

The fluid which lubricates the whole extent of the moveable surfaces by which the bones of the skeleton are articulated together, is not exclusively prepared by the membranous capsules which envelop the articulations. A number of reddish coloured cellular substances, placed in their vicinity, co-operate in the secretion. Though these parts, which were long considered as synovial glands, do not completely resemble the conglomerate glands, and although no glandular bodies, nor excretory ducts, can be demonstrated in them, they cannot, however, but be considered as fulfilling, to a certain degree, the same functions, and one must admit that they are of some utility, in the secretion of the synovia. They are always met with; their extent and bulk are always proportioned to the extent of the articular surfaces, and to the frequency of motion in the joints near which they are situated. They are found in all animals; pale and light coloured in those which have been long at rest; red, highly vascular and bearing the marks of a kind of inflammatory diathesis, in those which have been compelled to violent exercise, as the oxen which are brought to Paris from distant provinces, and the wild animals which have been hunted. In anchylosis, they are less red and of greater consistence, than in a healthy state.

When, from the irritation attending friction, the fluids are determined towards an articulation which is in motion, do they not then, by passing through those glandulo-cellular bodies, undergo a peculiar modification which renders them fitter for the secretion of synovia. This would not be the only instance, in the human body, of parts whose action is but secondary and connected with that of other organs principally engaged in a secretion whose materials are contained in the blood which passes through them. It will be urged, no doubt, that this preparatory apparatus is not met with in the neighbourhood of the great cavities: but it should be recollected, that the chemical composition and the uses of the synovia, are not precisely the same as those of the fluids secreted by the pleura or the peritoneum; and that, besides, the analogy between two objects, does not constitute their identity. The human mind being naturally indolent, loves to discover analogies that support it in its weakness, and that may save it the trouble of seeking points of difference. I am aware, that to prove that the mechanism of the synovial secretion, which exactly resembles that of the fluid which moistens the inside of the great cavities, requires like it but a simple membranous apparatus, it is customary to repeat, in every possible way, that Nature is scanty in her means, and lavish in her results; that she produces from the same cause, a variety of different effects, &c. but without pointing out the manifest absurdity of admitting metaphysical arguments in the natural sciences, is it not much more reasonable to acknowledge with philosophers, that the primitive cause may vary in many ways, and that its innumerable modifications, whence arise the difference in the effects, exceed the limited powers of our understanding?

CI. When a gland is irritated, it becomes a centre of fluxion, towards which the fluids are determined from every part; it swells, hardens, contracts, is in a kind of state of erection, bends on itself, and acts on the blood conveyed by its vessels. Secretion, depending on the peculiar and inherent power of the glandular organ, is promoted by the slight motion which it receives from the neighbouring muscles. The gentle pressure of those parts on the glandular organs, is sufficient to keep up their excitement and to assist in the separation and excretion of the fluid. Bordeu, in his excellent work on the glands and on their action, has shewn that it is not in consequence of the compression which is produced on them by the neighbouring muscles, that they part with the fluid they have prepared, that physiologists were therefore very much in the wrong, in saying, that the excretion of a fluid consisted merely in its expression, and in comparing, under that point of view, the glands to spunges soaked with a fluid which they give out, on being squeezed.

The excretory ducts of organs absorb or reject the secreted fluid, according as it affects their inhalant mouths; these canals partake in the convulsive state of the gland, undergo a degree of erection, and contract on the fluid to expel it. Thus, the saliva starts from the parotid duct, at the sight, or on the recollection of food that has been longed for: thus, the vesiculæ seminales and the urethra (for the reservoirs in which the fluids lie sometime before being expelled, may be considered as forming a part of the excretory ducts), contract, become straighter, and lengthen themselves to force to a distance the spermatic fluid.

The thin and transparent ureters of fowls, have been seen to contract on the urine which, in these animals, concretes, on the slightest stagnation.

After remaining a certain length of time, in that state of excitement, the glands relax, their tissue collapses, the juices cease to be conveyed to it as plentifully, they fall into a state of repose or sleep, which restores their sensibility, exhausted by too much action. It is well known, that a gland over-stimulated becomes, like any other part, insensible to the stimulus, the continued application of which parches and exhausts it.

From what has just been said relative to the mechanism of the secretions, it will be seen, that this function may be divided into three very distinct periods: 1st, that of irritation, characterized by the growth of the vital properties, and by the more copious accession of the fluids, the necessary consequence of that excitement; 2nd, the action of the gland; that is, its secretion, properly so called; 3d, lastly, the action by which the organ parts with the fluid which it has prepared; this is the last process, it is called excretion and is promoted by the action of the neighbouring parts. The determination of fluids to the part, the secretion and excretion succeed each other; they are preceded by the excitement which is the primary cause of all the subsequent phenomena. The circulation is, at first, excited, more blood is sent into the part, and penetrates into the tissue of the gland. Dr. Murat has had occasion to open a considerable number of old men, who died at the Bicêtre, and who were known to be great smoakers of tobacco. He uniformly observed, that their parotid glands, continually called into action by that habit, were larger than in those who were not given to it, and that they were remarkably red, in consequence of the blood with which they were constantly injected.

What is the office of the nerves in the act of secretion; what share has the nervous influence, in the elaboration of the fluids furnished by the glandular organs? All the glands which receive their nerves from the system of animal life, such as the lachrymal and salivary glands, appear, in certain cases, to receive, from the brain, the secretory excitation. The influence of the imagina tion is sufficient to determine it; thus, we shed involuntary tears, when the mind is taken up with painful thoughts; and the mouth fills with saliva, on the recollection of a grateful meal. In such cases, the influence of the nerves, on the process of secretion, is indisputable; it is not so, however, with the conglomerate glands that receive their nerves from the great sympathetics. The secretion of the kidneys, of the liver, and of the pancreas, appears less influenced by affections of the mind; the brain, besides, has no immediate connection with these glands; their nerves are, almost entirely, given off by the great sympathetics; the kidneys in particular, receive no nerves from the brain or from the spinal marrow, hence the secretion of urine seems, more than any other, to be independant of the nervous influence.

This great number of secretory organs, constantly engaged in separating various secretions from the mass of the fluids, would soon exhaust it, if the calculations of physiologists of the amount of what a gland is capable of secreting, were not manifestly exaggerated. In fact, if we admit, with Haller, that the mucous glands of the intestinal canal secrete, in twenty four hours, eight pounds of mucus; that, in the same space of time, the kidneys secrete four pounds of urine; that the same quantity is lost by the insensible perspiration; and again, as much by the pulmonary exhalation; there will be lost, daily, twenty pounds of fluids, almost entirely, excrementitious; for, we do not include in that calculation, the bile, the tears, nor the saliva and pancreatic fluid, which, in part, returns into the blood after being separated from it; nor the serum which moistens the internal surfaces, and which is purely recrementitious.

This exaggeration, in the calculation of the fluids which are daily poured out by the different emunctories, is to be attributed to the circumstance of having taken the maximum of each secretion, without considering that they mutually supply each other; so that, when less urine is voided, the quantity of perspiration is greater, and vice versâ. It is very well known, that a violent diarrhea is frequently the consequence of sudden cold applied to the skin; the fluids, at once repelled towards the intestinal canal, having to pass through the mucous glands whose action is greatly increased.

CII. It has been customary to enumerate, among the glands, certain bodies which have truly a glandular appearance; but the uses of which are yet unknown. Thus, the thyroid and thymus glands, which are parenchymatous organs destitute of excretory ducts, though receiving many vessels and some nerves, do not appear to secrete any fluid. But may not the blood, which is conveyed so plentifully to the thyroid gland, undergo nevertheless certain changes, though we may not be able to discover what they are. Besides, may not the lymphatics perform the office of excretory ducts and convey back again immediately into the mass of the blood, the fluid which has undergone changes in the glandular body? The capsulæ renales are in the same condition: they have, however, in addition, an internal reservoir, a kind of lacuna, whose parietes are smeared with a viscid and brown coloured substance secreted by the capsule, and which, doubtless, is conveyed into the mass of the blood by the lymphatics arising from the parietes of its internal cavity.

CIII. *Of the secretion of adeps within the cellular tissue.* This soft tissue which is diffused over the whole body, and affords a covering to all our organs, is of use not merely in separating them from one another, and in connecting together the different parts; it is, besides, the secretory organ of the adipose substance, a semi concrete oily animal substance which is found, in almost every part of the body, deposited in its innumerable cells. The membranous parietes of these small cellular cavities are supplied by numerous minute arteries, in which the adeps is separated; it is conveyed by its specific light weight to the circumference of the column of blood in the vessels, and transudes through the pores in their parietes. Its quantity and consistence vary, in different parts of the body, and in different persons: there is situated below the skin a thick layer of cellular substance (*panniculé graisseux*); it is found, in considerable quantity, between the interstices of the muscles, along the blood vessels, near the articulations and in the vicinity of certain organs, as the eyes, the kidneys, and the breasts. That which fills the bottom of the orbit, and which surrounds the eyeball, is softish and almost fluid; that which envelops the kidneys and the great joints is, on the contrary, of the consistence of suet. Between these two extremes, there are many gradations, and it may be said, that the animal oil in question, is not exactly the same in any two different parts of the body. The high temperature of the human body maintains it in a state of semi fluidity, as may be observed in surgical operations.

In some parts, it is even absolutely fluid, but its nature is then observed to be greatly changed, it no longer contains any oily substance and differs, but little, from a mere aqueous gelatine. Thus, the fluid in the cellular tissue of the eye-lids, of the scrotum, &c. has been considered by several physiologists, as absolutely different from fat. It may not be amiss to observe, that the laminæ of the cellular tissue, in such circumstances, yield more readily to extension, present a greater surface, form membranous expansions, and circumscribe cells of a considerable size, so that the differences in the secretion, perfecty coincide with the difference of structure. It may further be observed, that the functions of the eyelids and of the penis required that they should not contain any fat. Considerable deformity, when the person grew fat, would have been the consequence of the increased bulk of these parts, and besides, the folds of the skin would not have that free motion which their functions require. No real adeps is ever found within the skull, and the utility of this condition is very obvious. To how many dangers would not life have been exposed, if a fluid, so varying in quantity, and the amount of which may be trebled, in a very short space of time, had been deposited into a cavity accurately filled by an organ which is affected by the slightest compression?

In an adult male, of moderate *embonpoint*, the proportion of adeps is about one twentieth of the weight of the whole body, it is greater, in proportion, in children and in females; for, its quantity is always relative to the energy of the functions of assimilation. When digestion and absorption are performed with great activity, fat accumulates within the cellular substance; and if it be considered that it is but imperfectly animalized, that it bears the most striking analogy to the oils extracted from plants; that it contains very little azote and much hydrogen and carbon, like all other oily substances, since on distillation it is decomposed, and yields water and carbonic acid, with a very small quantity of ammonia; that its proportions are very variable, and may be considerably increased or diminished, without manifestly impairing the order of the functions; that animals that spend a great part of their life, without eating, seem to exist during their torpid state, on the fat which they have previously accumulated in certain parts of their body*; one will be led to think, that the state of fat is, to a portion of the nutritive matter extracted from the food, a kind of intermediate state, through which it has to pass before it can be assimilated to the animal whose waste it is destined to repair. Animals which live on grain and vegetables, are always fatter than those which live exclusively on flesh. Their fat is consistent and firm, while that of carnivorous animals, is almost completely fluid.

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* Marmots and dormice become prodigiously fat during the autumn, they then take to their holes and live in them, during the six winter months, on the fat

A corpulent man, on having his diet suddenly reduced, sensibly becomes thinner, in a very short time: the bulk and weight of his body diminishes, from the absorption of the fat which supplies the deficient quantity of blood. Adeps may, therefore, be considered as a substance in reserve, by means of which, notwithstanding the small quantity of food and its want of nutritious qualities, Nature, finds wherewith to repair the daily waste.

CIV. The use of adeps is not, as has been stated, on the authority of Macquer, to absorb the acids that are formed in the animal economy; that which is obtained from it, by distillation, (*the sebaceous acid*) is a new product formed by the combination of the oxygen of the atmosphere with the hydrogen, the carbon, and the small quantity of azote which it contains. The small quantity of this last substance nearly constitutes it into a vegetable acid. Fat has a considerable affinity for oxygen, and by combining with it, turns rancid, after remaining some time exposed to the air. It deprives metallic oxides of a part of their oxygen, and likewise, on being triturated with metallic substances, promotes their oxidizement. In proportion as it absorbs oxygen, its density increases; thus oils become concrete by combining with oxygen, and fat acquires a consistence almost equal to that of wax, which is itself a fatty substance highly oxidized.

Besides the principal use which we have assigned to adeps, and according to which, the cellular system may be looked upon as a vast reservoir in which there is deposited a considerable quantity of nutritive and semi-animalized matter, this fluid answers several purposes of secondary utility. It preserves the body in its natural temperature, being as well as the tissue of the cells in which it is contained, a very bad conductor of heat. Persons who are excessively corpulent, scarcely feel the most severe cold; the animals which inhabit northern climates, besides being clothed in a

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which is accumulated in all their organs. There is most fat collected in the abdomen, in which the epiploon forms masses of a considerable size. When, in the spring, their torpor ceases, and they awaken from their sleep, they are for the most part, exceedingly emaciated.

thick fur, are likewise provided with a considerable quantity of fat. The fishes of the frozen seas, the cetaceous animals which seldom go far from the polar regions, all kinds of whales, are covered with fat, and have likewise a considerable quantity within their body. By its unctuous qualities, fat promotes muscular contraction, the motion of the different organs, the free motion on each other of the different surfaces; it stretches and supports the skin, fills vacuities and gives to our limbs those rounded outlines, those elegant and graceful forms peculiar to the female body. Lastly, it envelops and covers over the extremities of the nerves, diminishes their susceptibility, which is always in an inverse ratio of the embonpoint, which induced a physician of merit to say, that the nervous tree, planted in the adipose and cellular substance, suffers, when from the collapse and the removal of that tissue, its branches are exposed, in an unprotected state, to the action of external causes as injurious to them, as the rays of the sun to a plant torn from its native soil. It is, in fact, observed, that nervous people are exceedingly thin, and have an excessive degree of sensibility. Too much fat, however, is as injurious as too small a quantity of it. I have seen several persons whose obesity was such, that besides being completely incapable of taking the slightest exercise, they were in great danger of suffocation. Respiration in such persons is, at times, interrupted by deep sighs, and their heart, probably overloaded with fat, expels, with difficulty, the blood within its cavities.

CV. According to modern chemists, the use of fat is to take from the system a part of its hydrogen. When the lungs or liver are diseased, when respiration or the biliary secretion do not carry out of the system, a sufficient quantity of that oily and inflammable principle, fat forms in a greater proportion. They appeal to the result of the experiment of shutting up a goose, whose liver is to be fattened, in a confined cage, placed in a hot and dark situation, and in gorging it with paste, of which it eats the more greedily, as being unable to stir, it gratifies its inclination to action, by exerting the organs of digestion. Notwithstanding this quantity of food, the bird becomes emaciated, is affected with a kind of marasmus, its liver softens, grows fatter, more oily, and attains an enormous size.

This experiment, and many other facts, prove, that the secretions from which analogous products are formed, may mutually supply each other; but can we admit the chemical theory of the use of fat when we recollect that frequently, in the most corpulent persons, respiration and the secretion of bile are performed with great freedom and with no difficulty; while the difficult respiration attending pulmonary consumption, and the difficult flow of the bile from an obstruction of the liver, are always accompanied with complete marasmus.

Whatever moderates the activity of the circulatory system, tends to bring on adipose plethora. Thus an inactive state of the mind and body, profuse bleedings, castration, sometimes induce obesity, an affection in which the cellular tissue appears affected with atony and undergoes an actual adipose infiltration, which may be compared to that which gives rise to tumours called steatomatous. If the energy of the heart and arteries is too great, emaciation is always the consequence; when, on the contrary, the sanguineous system is languid, there is formed a merely gelatinous fat and the embonpoint is a mere state of bloatedness.

This incompletely formed fluid, which distends the parts in persons of a leucophlegmatic habit, is but an imperfect kind of fat; it resembles the marrow or the medullary juice, which is merely a very liquid fat, whose consistence diminishes when animals become lean. Inclosed within the cells of the osseous tissue, in cavities whose sides cannot collapse, and whose dimensions must always remain the same, the marrow, of which they are never free, is of different degrees of density; and what authors say of its diminished quantity, must be understood as applying to the diminution of its consistence.

CVI. The secretion of the marrow is, like that of the fat, a mere arterial transudation; it is performed by the medullary membrane, which is thin, transparent, and cellular, which lines the inside of the central cavity of the long bones, and extends over all the cells of their spungy substance. The medullary membrane, when in a healthy state, does not give any marks of relative sensibility.—In all the amputations I have performed, and they have not been few, in all the operations of the same kind at which I have been present, whatever the bone was, whether it was divided near a joint or in the middle of its body, I never knew the patient complain of pain, provided the limb was well supported by the assistants and provided no jerk was given by the operator himself. In that operation, the pain occasioned by the division of the skin and of the nerves, overcomes every other pain, and I have always seen patients impressed with the popular prejudice, and expecting anxiously the division of the bone, feel quite free from pain, as soon as the saw had begun to work. Nay, several after expressing, by their cries, the most acute pain, taking advantage of the kind of ease which follows the division of the flesh, raise their head, and look on, while the bone is being sawn through; at once actors and spectators in this last part of a painful and bloody operation.

Yet the medullary membrane, the injury of which is attended with no pain, while in a healthy state, becomes the seat of the most exquisite sensibility in the pains in the bones which mark the last stages of the venereal disease; in the kind of conversion into flesh, of the solid bone, known by the name of spina ventosa, as will be mentioned, in speaking of the uses of the marrow, in the chapter on the organs of motion and on their action.

CHAPTER VI.

ON NUTRITION.

CVII. All the functions which we have hitherto made the object of our study; digestion, by which the alimentary substances received within the body, are deprived of their nutritive parts; absorption which conveys that recrementitious extract into the mass of the fluids; the circulation, by which it is carried to the parts wherein it is to undergo different changes; digestion, circulation, absorption, respiration, and the secretions, are but preliminary acts, preparatory to the more essential function treated of in this chapter, and the consideration of which terminates the history of the phenomena of assimilation.

Nutrition may be considered as the complement of the functions of assimilation. The aliment altered in its qualities, by a series of decompositions, animalized and rendered similar to the substance of the being which it is to nourish, is applied to the organs whose waste it is to repair; and this identification of the nutritive matter to our organs which take it up and appropriate it to themselves, constitutes nutrition. Thus, there is accomplished a real conversion of the aliment into our own substance.

There is incessantly going on a waste of the integrant particles of the living body, which a multiplicity of circumstances tend to carry away from it; several of its organs are constantly engaged in separating from it the fluids containing the recrementitious materials of its substance worn by the combined action of the air and of caloric, by inward friction and by a pulsatory motion that detaches its particles.

Alike, therefore, to the vessel of the Argonauts, so often repaired in the course of a long and perilous navigation, that on her return, no part of her former materials remained; an animal is incessantly undergoing decay, and if examined at two different periods of its duration, does not contain one of the same molecules. The experiment performed with madder, which dyes red, the bones of animals among whose food it is mixed, proves, most unquestionably, this incessant decomposition of animated and living matter. One has only to interrupt, for a sufficient length of time, the use of that plant, to make the uniformly red colour assumed by the bones, completely disappear. Now, if the hardest and most solid parts, most calculated to resit decay, are undergoing a perpetual motion of decomposition and of regeneration; there can be no doubt, that this motion must be far more rapid in those whose power of cohesion is much inferior; for example, in the fluids.

Attempts have been made to determine the period at which the body is completely renovated; it has been said, that an interval of seven years was required for one set of molecules to disappear and be replaced by others; but this change must go on more rapidly in childhood and in youth. It must be slower at a mature age, and must require a considerable time, at a very advanced period of life, when all the parts of the body become, in a remarkable degree, fixed and firm in their consistence, while the vital powers become more languid. There can be no doubt, that the sex, the habit, the climate in which we live, the profession we follow, our mode of life, and a variety of other circumstances, accelerate or retard it; so that it is absolutely impossible to fix, with any degree of certainty, its absolute duration.

CVIII. The parts of our body, in proportion as they undergo decay, are repaired only by means of homogeneous particles exactly like themselves: were it othewise, their nature, which always remains the same, would be undergoing perpetual changes.

When, in consequence of the successive changes which it has undergone from the action of the organs of digestion, of absorption, of the circulation, of respiration, and of secretion, the nutritive matter is animalized or assimilated to the body which it is to nourish, the parts which it moistens, retain it and incorporate it to their own substance. This nutritive identification is not performed alike in the brain, in the muscles, in the bones, &c. Each of them appropriates to itself, by a real process of secretion, whatever it meets with fitted for its nature, in the fluids conveyed to it by the different kinds of vessels, but especially by the arteries; it leaves unaffected, the remaining heterogeneous particles. A bone is a secretory organ, around which phosphate of lime is deposited; the lymphatic vessels which, in the process of nutrition, perform the office of excretory ducts, remove that saline substance, when it has lain sufficiently long in the cells of its tissue. The same happens to the muscles, with regard to fibrina, and to albumen with regard to the brain: every part appropriates to itself, and converts into a solid form, those fluids which are of the same nature, in virtue of a power of which the term affinity of aggregation, used in chemistry, gives an idea, and of which it is perhaps the emblem.

The nutrition of a part requires that it should be possessed of sensibility and motion; by tying the arteries and nerves of a part, it cannot be nourished nor can it live. The blood which flows along the veins, the fluid conveyed by the absorbents, contain, in a smaller proportion than arterial blood, vivifying and reparatory particles. It is even, commonly thought, that the lymph and venous blood contain no directly nutritive particles. As to the share which the nerves take in the process of nutrition, that is not yet completely determined. A limb that is paralized, by the division or tying of its nerves, or by any other affection, sometimes retains its original size and plumpness; most frequently, however, though perhaps for want of motion, it becomes parched, emaciated, and shrinks, in a remarkable degree.

CIX. We should be enabled to understand the process of nutrition, if after having accurately determined the difference of composition between our food, and the substance itself of our organs, we could see how each function robs the aliments of their qualities, to assimilate them to our own bodies; and what share each function takes in the transmutation of the nutritive particles into our own substance. To illustrate this point, suppose a man to live exclusively on vegetable substances which, in fact, form the basis of our food; on whatever part of the plant he may live, whether on the stem, on the leaves, on the blossoms, on the seeds, or on the root; carbon, hydrogen, and oxygen enter into the composition of these vegetable substances, which, by a complete analysis, may all be resolved into water and carbonic acid. To these three constituent principles, there is frequently united a small quantity of azote, of salts, and of other materials, in different proportions. If then, we examine the nature of the organs in this man, whose food is entirely vegetable, it will be found that they are different in their composition, and far more animalized than that kind of food; that azote predominates, though the vegetable substance contains none or only a very small quantity, that new products, undistinguishable in the aliments, exist, in considerable quantity, in the body which is fed on them, and appear produced by the very act of nutrition.

The essence of this function is, therefore, to make the nutritive matter undergo a more advanced state of composition, to deprive it of a portion of its carbon and of its hydrogen, to make azote predominate, and to produce several substances, which did not exist in it before. All living bodies seem to possess the faculty of composing and decomposing the substances by means of which they are maintained, and to form new products; but they possess it, in various degrees of energy. The sea weed, from the ashes of which soda is obtained, on being sown in a box of soil, in which there is not a single particle of that alkali, and watered with distilled water, will no longer contain it, as if it had grown on the sea shore, in the midst of marshes constantly inundated by salt and brackish water.*

Living bodies then, are real laboratories, in which there are carried on combinations and decompositions which art cannot imitate; bodies that appear to us simple, as soda and silex, seem to be formed by the union of their constituent particles; while other bodies, whose composition we do not understand, undergo an irresistible decomposition; hence, methinks, one may infer, that the power of Nature in the composition and decomposition of bodies, far exceeds that of chemistry.

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* I am unacquainted with the details of the experiment referred to by the author; he quotes it, I conceive, to shew that the power which, he says, is common to all living bodies, of producing a substance not supplied to them from without, is not possessed, in the same degree, by all bodies endowed with life: since the sea weed here alluded to, does not possess it, in an equal degree, when watered with distilled as with sea water. This, I apprehend, is the author's meaning, though the text is somewhat obscure, and would almost lead one to believe he meant, that no alkali whatever can be obtained from the sea plant under the circumstances he states, "L'algue marine dont les cendres fournissent "la soude, semèe dans une caisse pleine dún terreau qui ne contient pas un seul "atome de cet alkali, arrosée avec léau distillée, *ne le fournit plus* comme si elle "avoit pris sa croissance au milieù des marais toujours inondés par leurs eaux "saumâtres et muriatiques." T.

Straw and *cereal* plants contain an enormous quantity of silex, even when the earth in which they grow has been carefully deprived of its siliceous particles. Oats, particularly, contain a considerable quantity of that vitrifiable earth; the ashes obtained by burning its seed, on being analyzed by means of the nitric acid, were found by M. Vanquelin, to contain $\frac{607}{1000}$ of pure silex indissoluble in that acid, and 0,393 of phosphate of lime dissolved in it.

The excrements of a hen, fed, for ten days, on oats only, on being calcined and analyzed by the same chemist, produced twice as much phosphate and carbonate of lime as was contained in the oats, with a small deficiency in the quantity of silex, which might have been employed in furnishing the excess of calcareous matter; a transmutation depending on the absorption of an unknown principle, to the amount of nearly five times its own weight*.

CX. A substance to be fit for our nourishment, should be capable of decomposition and fermentation; that is, capable of undergoing an inward and spontaneous change, so that its elements and relations may be altered. This spontaneous susceptibility of decomposition, excludes from the class of aliments, whatever is not organized and is not a part of a living body; thus, mineral substances absolutely resist the action of our organs and are not convertible into their own substance. The common principle extracted from alimentary substances, however varied they may be, the *aliment*, as Hippocrates terms it, is, most probably, a compound highly subject to decomposition and fermentation; this is likewise, the opinion of all those who have endeavoured to determine its nature. Lorry thinks it is a mucous substance; Cullen says it is saccharine; Professor Hallé considers it as an hydro-carbonous oxide, which differs from the oxalic acid, only in containing a smaller quantity of oxygen. It is evident, that these three opinions are very much alike, since oxygen, carbon, and hydrogen, combined in different proportions, form the mucous and saccharine substances and the base of the oxalic acid. On analyzing the animal substance, by means of the nitric acid, it is reduced to this last base, by depriving it of a considerable quantity of azote which constitutes its most remarkable character.

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* See the *Annales de Chimie*, and the *Système des Connaissances chimiques* de Fourcroy, Tome X. page 72.

But whence comes this enormous quantity of azote? How happens it, that the flesh of a man living exclusively on vegetables, contains as much azote and ammonia, and is as putrescent, as that of a man living on animal food? Respiration does not introduce a single particle of azote in our fluids; this gas comes out of the lungs as it entered; the oxygen alone is diminished in quantity. Might not one suspect that this element of animal substances is a product of the vital action, and that instead of receiving it from our aliments, we form it within ourselves, by an act that is *hyper-chemical*; that is, which chemistry cannot imitate*?

CXI. It has been maintained, that the hydro carbonous oxide, combines, in the stomach and intestinal canal with oxygen, whether this last principle has entered, with the aliments, into the digestive tube, or whether it is furnished by the decomposition of the fluids within that cavity. The intestinal fluids extricate azote which combines with the alimentary mass, and occupies the place of the carbon which the oxygen has taken from it, to form carbonic acid. On reaching the lungs, and being again exposed to the action of the oxygen of the atmosphere, this gas robs it of a portion of its carbon, and as it disengages the azote of the venous blood, it brings about a new combination of that principle with the chyle: Lastly, propelled with the blood to the surface of the skin, the atmospherical oxygen disengages its carbon, and completes its *azotisation.* The cutaneous organ is perhaps to the lymphatic system, what the pulmonary organ is to the sanguineous system.

The animalization of the animal substance is therefore effected, principally by the loss of its carbon, which is replaced by the excess of azote in the animal fluids. These maintain themselves, in this manner, in a due temperament; for, continually parting with the carbonous principle in the intestinal, pulmonary, and cutaneous combinations, they would be over animalized, if an additional quantity of chyle did not seize the azote, which is in excess. Still, this theory does not account for the formation of the phosphoric salts, of the adipocere, and a variety of other products; but without adopting it, to the full, one may presume, from the experiments and facts on which it rests, that the oxygen of the atmospherical air is one of the most powerful agents employed by Nature, in the transformation of the aliments we live upon, into our substance.

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* The late experiments of Messrs. Allen and Pepys prove that when an animal is made to breathe pure oxygen, the blood disengages a certain quantity of azote and absorbs an equal quantity of oxygen. Philosophical Transactions, 1809.

How are those animals nourished which live solely on more animalized flesh, that is containing a greater quantity of azote, and a greater proportion of ammonia than their own substance. In such a case, the assimilation of the aliments, consists in their *desanimalization* either, by the co-operation of all the organs, or by the sole action of the digestive organs, by the combination of the gastric juice with the other fluids.

The constituent elements entering into the composition of our organs, whether coming from the exterior, or formed by the vital power itself, are thrown out of our body, by the different emunctories, and cease to form a part of it, after remaining within it, for a limited time. The urine carries along with it, an enormous quantity of azote, the lungs and the liver rid us of the carbon and of the hydrogen; the oxygen which contains eighty-five parts in the hundred, in the composition of water, is evacuated by means of the aqueous secretions which carry off, in a state of solution, the saline and other soluble principles.

Among those salts there is one, but little soluble, and which, nevertheless, is of primary consequence among the constituent principles of the animal economy. Phosphate of lime, in fact, forms the base of several organs, it, almost entirely, forms the osseous system, at an advanced period of life; all the white organs; all our fluids contain a remarkable quantity of that substance, of which the economy rids itself by a kind of *dry* secretion. The outer covering is, in all animals, the emunctory destined for that purpose; the annual moulting of birds, the fall of the hair of quadrupeds, the renovation of the scales of fishes and reptiles, carry off, every year, a considerable quantity of calcareous phosphate. Man is subject to the same laws, with this difference, that the annual desquamation of the epidermis, is not under the absolute influence of the seasons, as in the brute creation. The human epidermis is renewed annually, as well as the hair on the head and on the body; but this change is brought about gradually, and is not completed in a season; it does not take place in the spring, as in most animals, nor in autumn with the fall of the leaf, though at these two periods, the hair falls off in greatest quantity, and the desquamation of the cuticle is most active. These two phenomena last throughout the whole year, as in southern climates, the fall of the leaves and the renovation of vegetation are continually going on. As will be mentioned, in speaking of the functions of generation, man living in a state of society, and enjoying all the advantages of civilization, is not as much under the influence of the seasons as the inferior animals. One cannot, however, but observe, that the successive shedding and renewing of the epidermoid parts, as the cuticle, the nails, and the hair, are among the most effective means which nature possesses of parting with the phosphate of lime, so abundant in all animals, and which, nevertheless, is so insoluble and consequently so unfit to be carried out of the system, along with the excrementitious fluids. This effect is very remarkable, on the termination of several diseases, in the salutary renovation of the solids and fluids which takes place during convalescence. The hair ceases to grow on the bald head of an old man; his perspiration diminishes; may not this be the cause of the great quantity of calcareous salts, of the ossification of the vessels, of the induration of the membranes?

CXII. What is the ultimate result presented to us, by this series of functions, linked together, growing out of one another, and all acting on the matter of nutrition, from the moment it is received within the body, till it is applied to the growth and reparation of its organs? It shows us man living within himself, unremittingly employed in converting, into his own subtance, heterogeneous substances, and reduced to an existence purely vegetative, inferior even to the greater part of organized beings, in his powers of assimilation. But how high is he not placed above them all, in the exercise of those functions we are now about to contemplate, functions, which raise him above his own nature, which enlarge the sphere of his existence, which serve him to provide for all his wants, and to keep up, with all Nature, those manifold relations which subject her to his empire!

FIRST CLASS.

SECOND ORDER.

Functions which tend to the preservation of the Individual, by establishing his relations with the beings that surround him.

CHAPTER VII.

OF SENSATIONS.

CXIII. We have already seen, how the human body, essentially changeable and perishable, maintains itself in its natural economy, carries on its growth, and supplies its decay, by assimilating to its own substance, principles that are yielded to it by the food it digests, and by the air it breathes. We shall now proceed to examine, by what organs man is enabled to keep up, with all nature, the relations on which his existence depends: by what means he is made aware of the presence of objects which concern him, what means he possesses to fit his connexion with them to his welfare, to draw them towards him or to repel them, to approach or to avoid and escape them, as he perceives in them danger, or the promise of enjoyment.

Man possesses, in all its plenitude, this new mode of existence, which is denied to vegetable Nature. Of all animals it is he that receives impressions the most crowded and various, that is most filled with sensations, and that employs them, with the most powerful combination, as the materials of thought, and the sources of intelligence: he is the best organized for feeling the action of all beings around him, and re-acting on them in his turn. In the study which we are about to undertake, we shall see many instruments placed on the limits of existence, on the surface of the living being, ready to receive every impression; conductors, stretching from these instruments to one common centre, to which all his carried: conductors through which this central organ regulates the actions, which now transport the whole body from one place to another (*locomotion*); now merely change the relative situation of its parts (*partial motion*); and, at other times, produce, in the organs, certain dispositions, of which speech and language, in their various forms, are the result.

CXIV. If we are thoroughly to understand the mechanism of this action of outward objects on our body, we must follow the natural succession of the phenomena of sensation; studying first, the bodies which produce the sensitive impression, examining next, the organs that receive it, and next the conductors which transmit it to a particular centre whose office is perception. To take the sense of sight, for instance, we can never understand how it is that light procures us the knowledge of certain qualities of bodies, if we have not learnt the laws to which that fluid is subjected, if we know nothing of the conformation of the eyes, of the nerves by which those organs communicate with the brain, and of the brain itself, whither all sensations, or rather the motions in which they consist, are ultimately carried.

CXV. *Of light.* At this day, the greater part of Natural Philosophers consider it as a fluid impalpable from its exceeding tenuity. Many believe it to be only a modification of caloric, or of the matter of heat; and this last opinion has received much plausibility from the late observations of Herschel.* I shall not examine whether, as Descartes and his followers imagine, light, consisting of globular molecules, exist of itself, uniformly diffused through space, or as Newton has taught us to believe, it be but an emanation of the sun and fixed stars, which throw off, from their whole surface, a part of their substance, without ever exhausting themselves by this continual efflux: It is enough for us to know, 1st, that the rays of this fluid move with such velocity, that light passes, in a second, through a distance of seventy two thousand leagues, since, according to the calculation of Roëmer and the tables of Cassini, it traverses in something less than eight minutes, the thirty-three millions of leagues that separate us from the sun; 2dly, that light is called *direct*, when it passes from the luminous body to the eye, without meeting any obstacle; *reflected*, when it is thrown back to that organ by an opake body; *refracted*, when its direction has been changed, by passing from one transparent medium to another of different density; 3dly, that the rays of light are reflected at an angle equal to that of incidence; that a ray, passing through a transparent body, is more strongly refracted as the body is more convex on the surface, denser, or of more combustible elements. It was from this last observation, that Newton conjectured the combustibility of the diamond, and the existence of a combustible principle in water, since placed beyond doubt, by the beautiful experiments of modern chemistry; 4thly, that a ray of light refracted by a glass prism is decomposed into seven rays, red, orange, yellow, green, blue, indigo, and violet. Each of these rays is less refrangible, as it is nearer to the red. This ray is of all, that which strikes the eyes with the greatest force, and produces on the retina the liveliest impressions. The eagerness of savages for stuffs of this colour is well known. Among almost all nations it has dyed the mantle of Kings: it is the most brilliant and splendid of all: there are animals whose eyes seem scarcely to sustain it: I have seen maniacs whose madness, after a long suspension, never failed to break out, at the sight of a red cloth, or of one cloathed in that colour. Green is, on the contrary, the softest of colours; the most permanently grateful; that which least fatigues the eyes; and on which they will longest and most willingly repose. Accordingly, Nature has been profuse of green, in the colouring of all plants; she has dyed, in some sort, of this colour, the greater part of the surface of the globe. When the eyes bear uneasily the glare of too strong a light, glasses of this colour are used to soften the impression, which slightly tinge, with their own hue, all the objects seen through them. Lastly, the violet ray, last in the scale, of which the middle place is filled by the green, is of all the weakest, the most refrangible. Of all colours, violet has the least lustre; forms shew to less advantage under it; their prominences are lost; painters accordingly make but little use of it. When an enlightened body reflects all the rays, the sensations they might separately produce, blend into the sensation of white; if it reflect a few, it appears differently coloured, according to the rays it repels: finally, if all be absorbed, the sensation of black is produced, which is merely the negation of of all colour. A black body is wrapped in utter darkness, and is visible only by the lustre of those that surround it; 5thly, that from every point in the surface of a luminous or enlightened body, there issue a multitude of rays, diverging according to their distance, with a proportionate diminution of their effect; so that the rays from each visible point of the body, form a cone, of which the summit is at that point, and the base, the surface of the eye on which they fall.

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* This celebrated Astonomer has published, in the Philosophical Transactions of the Royal Society for 1800, a series of experiments which shew, that the different coloured rays, heat, in different degrees, the bodies on which they fall, and that the red ray, which is the least refrangible, gives also the greatest heat.

The thermometer placed out of the spectrum and towards the red ray, so that it would receive any rays yet less refrangible, rises higher than when it is placed in that colour: From which Herschel concludes that rays are given out by the sun, too little refrangible to produce the sensation of light, and of colours, but which produce the sensation of heat.

CXVI. *Sense of sight.* The eyes, the seat of this sense, are so placed, as to command a great extent of objects at once, and enclosed in two osseous cavities, known by the name of orbits. The base of these cavities, is forwards, and shaped obliquely outwards; so that their outward side not being so long as the others, the ball of the eye supported, on that side, only by soft parts, may be directed outwards and take cognizance of objects placed to a side, without its being necessary, at the same time, to turn the head. In proportion as we descend from man in the scale of animated beings, the shape of the base of the orbits becomes more and more oblique; the eyes cease to be directed forward, in short, the external side of the socket disappears, and the sight is entirely directed outward, and as the physiognomy derives its principal character from the eyes, its expression is absolutely changed. In certain animals very fleet in running, such as the hare, the lateral situation of the organs of vision, prevents the animals from seeing small objects, placed directly before them, hence those animals, when closely pursued, are so easily caught in the snares which are laid for them.

The organ of sight consists of three essentially distinct parts. The one set intended to protect the eye ball, to screen it, at times, from the influence of light, and to maintain it in the conditions necessary to the exercise of its functions; these parts are the eye-brows, the eye-lids, and the lychrymal apparatus, and they serve as appendages of the organ. The eye-ball itself contains two parts answering very different purposes; the one, formed by nearly the whole globe, is a real optical instrument, placed immediately in front of the retina, and destined to produce on the luminous rays those changes which are indispensable, in the mechanism of vision; the other, formed by the medullary expansion of the optic nerve, is the immediate organ of that function. It is the retina, which alone is affected by the impression of light, and set in motion by the contact of that very subtle fluid. This impression, this motion, this sensation, is transmitted to the cerebral organ, by the optic nerve, the expansion of which forms the retina.

CXVII. *Of the eye-brows, the eye-lids, and the lachrymal apparatus* (*Tutamina oculi*, Haller). The more or less dark colour of the hairs of the eye-brows, renders that projection very well adapted to diminish the effect of too vivid a light, by absorbing a part of its rays. The eye-brows answer this purpose, the more completely, from being more projecting, and from the darker colour of the hairs which cover them; hence we depress the eye-brows, by knitting them transversely, in passing from the dark, into a place strongly illuminated, which causes an uneasy sensation to the organ of sight. Hence, likewise, the custom that prevails with some southern nations, whose eye-brows are shaded by thicker and darker hairs, to blacken them, that they may still better answer the purpose for which they are intended.

The eye-lids are two moveable curtains, placed before the eyes which they alternately cover and uncover. It was requisite that they should be on the stretch and yet capable of free motion; now, both these ends are obtained by the tarsal cartilages, which are situated along the whole of their free edges and of the muscles which enter into their structure. The cellular tissue, which unites the thin and delicate skin of the eye-lids to the muscular fibres, contains, instead of a consistent fat, which would have impeded its motion, a gelatinous lymph which, when in excess, constitutes œdema of the eye-lids. The tissue of the eye-lids is not absolutely opaque, since, even when strongly drawn together, and completely covering the globe of the eye, one may still discern through their texture, light from darkness. On that account, light may be considered as one of the causes of awakening, and it is of consequence to keep in the dark, patients fatigued by want of sleep.

The principal use of the eye-lids is to shade the eyes from the continual impression of light. Like all the other organs, the eyes require to recruit themselves by repose; and they had not been able to enjoy it, if the incessant impression of the luminous rays had continually excited their sensibility. The removal of the eye-lids is attended with loss of sleep. The fluids are determined to the affected organ which suffers from incessant irritation. The eyes inflame, the inflammation spreads towards the brain, and the patient expires in the most dreadful agony. Thanks to an advanced state of civilization, these barbarous tortures have long been abolished; but what happens, when from ectropium of one or other of the eye-lids, a small portion of the sclerotic coat or cornea remains uncovered, proves the indispensable necessity of those parts. The spot exposed to the continued action of the air and of the light, becomes irritated and inflamed and there comes on an opthalmia, which can be cured only, by bringing together, by means of a surgical operation, the divided edges of the opening which is the cause of the affection. From the moveable edges of both eye-lids, there arise short curved hairs, of the same colour as those of the eye-brows; they are called eye-lashes and are intended to prevent insects, or other very light substances, floating in the atmosphere, from getting between the eye-ball and the eye-lids.

The anterior part of the eye, thus defended against external injuries, is continually moistened by the tears. The organ which secretes this fluid, is a small gland situated in a depression at the anterior and external part of the arch of the orbit, imbedded in fat, and supplied with pretty considerable vessels and nerves in proportion to its bulk, and pouring the fluid it secretes, by means of seven or eight ducts which open on the internal surface of the upper eye-lid, by capillary orifices directed downward and inward. The tears are a muco serous fluid, rather heavier than distilled water, saltish, changing to a green colour, vegetable blues, and containing soda, muriate and carbonate of soda, and a very small quantity of phosphate of soda and of lime.

In opthalmia, the irritation of the conjunctiva, transmitted by sympathy, to the lachrymal gland, not only augments the quantity of its secretion, but appears, likewise, to alter the qualities of the fluid that is secreted. The tears which, in those cases, flow in such profusion, bring on a sense of burning heat in the inflamed part; do they not, perhaps, contain a greater quantity of the fixed alkali than in the ordinary state of the parts, and may not the painful sensation depend as much on the increased proportion of soda in the tears, as on the greater sensibility of the conjunctiva?

This last membrane is merely a fold of the skin, which is exceedingly thin, covers the posterior surface of the eye-lids, and is then reflected over the anterior part of the eye which it thus unites to the eye-lids. From the whole extent of its surface, there oozes an albuminous serosity which mingles with the tears, and adds to their quantity.*

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* There is no opening in the part which corresponds to the globe of the eye; it is exceedingly thin and is continued, under the name of conjunctiva, over

The tears are equably diffused over the globe of the eye, by the alternate motions of the palpebræ; they prevent the effects of friction, and save the organ of sight from being dried, at that part which is exposed to the air. The air dissolves and carries off, in evaporation, a part of the lachrymal fluid. This evaporation of the tears is proved by the weeping to which those in whom that secretion is very profuse, are subject, whenever the atmospherical air, from being damp, does not carry off a sufficient quantity of the fluid. The unctuous and oily fluid, secreted by the meibomian glands, smears the loose edge of the palpebræ, prevents the tears from falling on the cheek, and answers the same purpose as the greasy substance with which one anoints the edges of a vessel, filled above its level, to prevent the overflowing of the contained fluid.

The greatest part of the tears, however, flow from without inward and towards the inner canthus of the eye; they take that direction in consequence of the natural slope of the moveable edge of the palpebræ, of the triangular groove, which is formed behind the line of union of their edges whose round and convex surfaces touch each other only in a point, and this course of the tears is likewise promoted by the action of the palpebral portions of the orbicularis palpebrarum, whose fibres, having their fixed point at the inner angle of the orbit, where the tendon is inserted, always draw inward their external commissure.

On reaching the internal angle of the palpebræ, the tears accumulate in the *lacus lachrymalis*, a small space formed between the edges of the palpebræ kept separated from each other by the *caruncula lachrymalis*. This last substance, long considered by the antients as the secretory organ of the tears, is merely a collection of mucous cryptæ covered over by a loose fold of the conjunctiva. These follicles, alike in nature to the meibomian glands, secrete like them, an unctuous substance, which smears the moveable edges of the palpebræ, near the internal commissure. The edges of the

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the transparent cornea, to which it adheres so firmly, that it is not easily separated from it. In some animals that have no palpebræ, the skin is continued, of the same thickness, over the fore part of the eye. The conjunctiva (if, however, this portion of skin deserves that name) when opaque, renders the globe of the eye, i other respects imperfect, absolutely useless. This is observed in the kind of eel called, in books of natural history, *murena cæcilia*: the *gastrobranchus cæcus* is blind from the same circumstance.

eye-lids, in this situation, required a thicker coating, as the tears accumulated in that spot have no where a greater tendency to flow on the cheek.

Near the union of the inner sixth of the free edge of the palpebræ with the remaining five sixths, at the outer part, where their internal, straight, or horizontal portion unites with the curved part, there are situated two small tubercles, at the top of each of which there is a minute orifice. These are the puncta lachrymalia, and they are called superior and inferior, according to the palpebræ to which they belong. In the dead body, the puncta do not appear tubercular, the small bulgings produced, doubtless, by a state of orgasm and of vital erection, collapse at the approach of death. These small apertures, directed inward and backward, are incessantly immersed in the accumulated tears, absorb them and convey them into the lachrymal sac, by means of the lachrymal ducts of which they are the external orifices. The absorption of the tears and their flow into a membranous reservoir lodged in the groove formed by the os unguis, do not depend on the capillary attraction of the lachrymal ducts; each of them, endowed with a peculiar vital action, takes up, by a real process of suction, the tears accumulated in the *lacus lachrymalis*, and determines their flow into the sac. The weight of the fluid, the effort of the columns which succeed each other, co-operate with the action of the parietes of the duct. The flow of the tears is further facilitated by the compression and slight concussions attending the contractions of the palpebral fibres of the orbicularis, behind which the lachrymal ducts are situated. This vitality of the puncta lachrymalia and of the ducts is readily discovered, when we attempt to introduce into them Anel's syringe or Mejean's stylet, to remove slight obstructions of the lachrymal passages. In a child now under my care, for a mucous obstruction of the nasal duct, I can see the puncta lachrymalia contract, when the extremity of the syphon does not, at once, enter the canal. One is then obliged to wait, before it can be introduced, for a cessation of the spasmodic contraction, which lasts but a few moments. The tears which flow into the lachrymal sac, by the common orifice of the united puncta lachrymalia, never accumulate within it, except in case of morbid obstruction; they, in that case, at once enter into the nasal duct which is a continuation of it, and fall into the nasal fossæ, below the anterior part of the inferior turbinated bones of these cavities. There, they unite with the mucous of the nose, increase its quantity, render it more fluid, and change its composition. The use of the tears is to protect the eye-ball against the irritating impression of the immediate contact of the atmosphere. They, at the same time, favour the sliding of the palpebræ, lessen the friction in those parts and in the eye-ball, and thus promote their motion.

CXVIII. *Of the globe of the eye.* The eye-ball, as was already observed, may be considered as a dioptrical instrument placed before the retina; whose office it is to refract the luminous rays, and to collect them into one fasciculus, that may strike a single point of the nervous membrane exclusively calculated to feel its impression. An outer, membranous, hard, and consistent covering supports all its parts. Within the first membrane called the sclerotic, lies the choroid, a darkish coat, which lines the inside of the sclerotic, and forms the eye into a real camera obscura. At the anterior part of the globe, there is a circular opening in the sclerotic in which the transparent cornea is inserted. At about the distance of the twelfth part of an inch from this convex segment, received in the anterior aperture of the sclerotica, lies the iris, a membranous partition placed perpendicularly, and containing a round opening (the pupil), which dilates or contracts, according to the state of dilatation or contraction of the iris.

At the distance of about half a line from the back part of the iris, towards the union of the anterior fourth of the globe of the eye with the posterior three fourths, opposite to the opening of the pupil, there is situated a lenticular body, inclosed in a membranous capsule, immoveably fixed in its situation by adhering to the capsule of the vitreous humour.

Behind the crystalline lens, the posterior three fourths of the cavity of the eye contain a viscid transparent humour, enclosed in the cells of a remarkably fine capsule, called hyaloid. This vitreous humour forms about two thirds of a sphere from which the anterior segment had been taken out; the pulpous expansion of the optic nerve, the retina, is spread out on its surface, so as to be concentrical to the choroid and sclerotic coats.

The eye-ball being nearly spherical, the length of its different diameters differs but little. The diameter of the eye, from the fore to the back part, is between ten and eleven lines, the transverse and vertical diameters are somewhat shorter. Within the space measured by the diameter from the fore to the back part, there are situated, taking them in their order from the fore part, the cornea, the aqueous humour contained in the anterior chamber, the iris and its central opening or pupil; the aqueous humour of the posterior chamber; the crytalline lens, surrounded by the ciliary processes; then, the vitreous humour in its capsule, and behind those transparent parts of the eye, through which the luminous rays pass, in approaching to a perpendicular, are the retina which receive the impression, the choroid whose black paint absorbs the rays that pass through the thin and transparent retina, and the sclerotic in which there is an opening for the passage of the optic nerve to the globe of the eye.

The cornea, contained in the anterior aperture of the sclerotica, like the glass of a watch case within its frame, is about the third of a line in thickness; it forms, at the fore part of the eye, the segment of a smaller sphere; behind it lies the aqueous humour which fills what are called the chambers of the eye, these form spaces divided into anterior and posterior, the former, which is the larger of the two, bounded by the cornea at the fore part and by the iris at the back part; the latter, which is smaller and separates the crytalline humour from the iris, the posterior part of which, covered by a black pigment, is called the *uvea*.* The specific gravity of the aqueous humour does not much exceed that of distilled water; some have even thought it less; it is the albuminous

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* Some anatomists have doubted the existence of the posterior chamber of the eye; but to be convinced of its existence, one need but freeze an eye, when there will be found a piece of ice, between the crytalline lens and the uvea. The formation of this icicle is not owing to the admission, through the opening of the pupil, of the aqueous humour which, like all other fluids, expands considerably on freezing, for, the expansion of fluids on their freezing being proportioned to their bulk, the vitreous humour which freezes at the same time as the aqueous, must prevent its retrogade flow through the pupil. Lastly, the uvea or posterior part of the iris is covered with a black point which is easily detached from it; now, if the anterior part of the crystalline lens had been in immediate contact with it, it would have been soiled by some of this colouring matter which would have tarnished its natural transparency, indispensable to perfect vision. It is, therefore, undeniable that there does exist a posterior chamber, which is to the anterior in the proportion of two to five, and containing about two fifths of the aqueous humour, the whole of which is estimated at five grains, and that the iris forms a loose partition between the two portions of the aqueous humour in which the dark pigment of the uvea is insoluble. The aqueous humour appears to be the product of arterial exhalation; it is soon reproduced, as we see after the operation for cataract.

and holds in solution several saline substances. The crystalline, inclosed in its membranous and transparent capsule, is a lenticular body rather solid than fluid; its consistence is particularly great towards its centre; it there forms a kind of nucleus, on which are laid several concentric layers, whose density diminishes as they approach the surface, where the external layers, truly fluid, form what Morgagni considered, as a peculiar liquid on which the lens might be nourished by a kind of imbibition. This body, composed of two segments of unequal convexity, about two lines in thickness, at its centre, consists of an albuminous substance coagulable by heat and alkohol. Extremely minute arteries given off by the central artery of Zinn, pass through the vitreous humour, and bring to it the materials of its growth and reparation.

The vitreous humour, so called from its resemblance to melted glass, is less dense than the crystalline and more so than the vitreous, and is in considerable quantity in the human eye; it appears to be secreted by the minute arteries which are distributed to the parietes of the membrane of the vitreous humour; it is heavier than common water, somewhat albuminous and saltish.

The sclerotica is a fibrous membrane to which the tendons which move the globe of the eye are attached; it supports all the parts of that organ, and these collapse and decay, whenever the continuity of its external covering is destroyed. The use of the choroid, is not so much to afford a covering to the other parts, as to present a dark surface, destined to absorb the luminous rays, when they have produced on the retina a sufficient impression. If it were not for the choroid, the light would be reflected, after having impinged on the nervous membrane, its rays would cross, and produce only indistinct sensations. Mariotte thought that the choroid was the immediate seat of vision, and that the retina was only its epidermis. This hypothesis would never have obtained so much celebrity, if, besides the objections that analogy might have furnished against it, there had been adduced, in opposition to it, the fact observed in fishes, in which the choroid is separated from the retina, by a glandular body, opaque and incapable of transmitting the luminous rays. The retina loses its form, as soon as it is separated from the vitreous humour, or from the choroid coat, between which it is spread out as a very thin capsule, so soft as to be almost fluid. A number of blood vessels, from the central artery of Zinn, are distributed on the nervous substance of the retina, and give it a slight pink colour. Ought we, with Boerhaave, to attribute to aneurismal or varicose enlargements of those small vessels, the spots which are seen in objects, in the disease to which Maitre Jean gave the name of *imaginations*? In order to form the retina, the optic nerve which penetrates into the globe of the eye, by piercing the sclerotica, to which the covering given to that nerve by the dura mater is connected; the optic nerve, penetrates through a very thin membrane perforated by a number of small holes and closing the opening left by the nerve, and which belongs as much to the choroid as to the sclerotic coats, it then spreads out to furnish the expansion which lines the concavity of the choroid and covers over the convex surface of the vitreous humour. The whole extent of the retina, which is equally nervous and sentient, may receive the impression of the luminous rays, though this faculty has, by several philosophers, been exclusively assigned to its central part, called the optical axis or porus opticus. This central part is easily recognized, in man, by a yellow spot discovered by Söemmering; in the middle of this spot, situated at the outer side of the entrance of the optic nerve into the globe of the eye, there is seen a dark spot and a slight depression, the use of which is not understood. This peculiar structure, recently discovered, is met with only in the eye of man and of monkeys.

CXIX. *Mechanism and phenomena of vision.* The rays of light passing from any point of an enlightened object, form a cone of which the apex answers to the point of the object, and of which the base covers the anterior part of the cornea. All the rays, more diverging, which fall without the area of the cornea on the eyebrows, the eye-lids, and the sclerotica are lost to vision. Those which strike the mirrour of the eye pass through it, under a refraction proportioned to the density of the cornea, which much exceeds that of the atmosphere, and to the convexity of that membrane: approaching the perpendicular, they now pass through the aqueous humour, less dense, and fall upon the membrane called the iris. All those that fall upon this membrane are reflected, and shew its colour, different in different persons, and apparently depending on the organic texture, and on the particular and very diversified arrangement of the nerves, of the vessels, and cellular tissue, which enter into its structure. None but the most central traverse the pupil and serve to sight. These will pass that opening, in greater or less number, as it is more or less dilated. Now, the pupil is enlarged or diminished, by the contraction or expansion of the iris.

The motions of this membrane depend entirely on the manner in which light affects the retina. The iris itself is insensible to the impression of the rays of light, as Fontana has proved, who always found it immoveable, when he directed on it alone the luminous rays. When the retina is disagreeably affected, by the lustre of too strong a light, the pupil contracts, to give passage only to a smaller number of rays: it dilates, on the contrary, in gloom, to admit enough to make the requisite impression on the retina.

To explain the motions of the iris, it is not necessary to admit that muscular fibres enter into its structure; it is enough to know its vascular, spungy and nervous texture; the irritation of the retina sympathetically transmitted to the iris, determines a more copious afflux of humours; its tissue dilates and stretches, the circumference of the pupil is pushed towards the axis of this opening, which becomes contracted by this vital expansion of the membranous tissue. When the irritating cause ceases to act, by our passing from light into darkness, the humours flow back into the neighbouring vessels, the membrane of the iris returns upon itself, and the pupil enlarges, the more as the darkness is greater.*

The rays, admitted by the pupil, pass through the aqueous humour of the posterior chamber, and soon meet the crystalline, which powerfully refracts them, both from its density, and its lenticular form. Brought towards the perpendicular by this body, they pass on towards the retina through the vitreous humour, less dense, and which preserves, without encreasing it, the refraction produced by the crystalline lens. The rays, gathered into one, strike on a single point of the retina, and produce the impression which gives us the idea of certain properties of the body which reflects them. As the retina embraces the vitreous humour, it presents a very extended surface to the contact of the rays, which enables us to behold, at once, a great diversity of objects, variously situated towards us, even when we or these objects change our relative situation. The luminous rays, refracted by the transparent parts of the eye, form therefore, in the interior of the organ, a cone, of which the base covers the cornea, and applies to that of the external luminous cone, whilst its apex is on some point of the retina. It is conceived, generally, that the luminous cones issuing from all points of the object beheld, cross in their passage through the eye, so that the object is imaged on the retina reversed. Admitting this opinion, established on a physical experiment, we have to enquire, why we see objects upright, whilst their image is reversed on the retina. The best explanation we possess of this phenomenon, we owe to the philosopher Berkeley, who proposed it in his English work, entitled *Theory of Vision*, &c. In his opinion, there is no need of the touch to correct this error into which sight ought to betray us. As we refer all our sensations to ourselves, the uprightness of the object is only relative, and its inversion really exists at the bottom of the eye.

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* Habitual dilatation of the pupil is a symptom of weakness, of worms, &c.

By the *point of distinct vision*, is understood the distance at which we can read a book of which the characters are of middling size, or distinguish any other object equally small. This distance is not confined within very narrow limits, since we can read the same book at six inches from the eye, or at five or six times the distance. This faculty of the eyes to adapt themselves to the distance and the smallness of objects, cannot depend, as has been fondly repeated, on the lengthening or shortening of the globe of the eye by the muscles that move it. Its four recti muscles are not, in any case, capable of compressing it on its sides, nor of lengthening it by altering its spherical form; their simultaneous action can only sink the ball in its socket, flatten it from the fore to the back part, diminish its depth, and make the refraction, consequently, less powerful, when objects are very distant or very small: this last effect, even, might be disputed. The eye which moves and rests on the adipose cushion which fills the bottom of the socket, is never strongly enough pressed to lose its spherical figure, which of all the forms in which bodies can be invested, is that which, by its especial nature, best resists alteration. The extremities of the ciliary processes, which surround the circumference of the crytalline lens, cannot act on this transparent lens, compress nor move it: for, these little membranous folds, of which the aggregate composes the irradiated disk, known under the name of corpus ciliare, possessing no sort of contractile power, are incapable of moving the crytalline lens with which their extremities lying in simple contiguity have no adherence, and which, besides, is immoveably fixed in the depression which it occupies, by the adhesions of its capsule with the membrane of the vitreous humour. The various degrees of contraction or dilatation of which the eye-ball is susceptible, afford a much more satisfactory explanation of this physiological problem.

The rays of light which come from a very near object, are very divergent: the eye would want the refracting power necessary to collect them into one, if the pupil, contracting by the enlargement of the iris, did not throw off the the more divergent rays, or those which form the circumference of the luminous cone. Then, those which form the centre of the cone, and which need but a much smaller refraction for their re-union on a single point of the retina, are alone admitted by the straitened opening. When, on the contrary, we look at a distant object from which rays are given out, already very convergent, and which need but a small refraction to bring them towards the perpendicular, we dilate the pupil, in order to admit the more diverging rays, which, when collected, will give the image of the object. In this respect, very small bodies are on the same footing as those at a great distance.

Though the image of every object is traced at the same time in both our eyes, we have but one sensation, because the two sensations are in harmony and are blended and serve only, one aiding the other, to make the impression stronger and more durable. It has long been observed, that sight is more precise and correct when we use only one eye, and Jurine thinks that the power of the two eyes united exceeds only by one-thirteenth, that of a single eye. The correspondence of affection requires the direction of the optical axes on the same objects, and be that direction ever so little disturbed, we see really double which is what happens in squinting.

If the eyes are too powerfully refractive, either by the too great convexity of the cornea and the crystalline, the greater density of the humours, or the excessive depth of the ball, the rays of light, too soon re-united, diverge anew, fall scattering on the retina, and yield only a confused sensation. In this defect of sight, called *myopia*, the eye distinguishes only very near objects, giving out rays of such extreme divergence as to require a very powerful refractor. In *presbytia*, on the other hand, the cornea too much flattened, the crytalline little convex, or set too deeply, the humours too scanty, are the cause that the rays are not yet collected when they fall upon the retina, so that none but very distant objects are distinctly seen, because the very[*] convergent rays they give out, have no need of much refraction.

Myopia is sometimes the effect of the habit which some children get, of looking very close at objects which catch their attention. The pupil then becomes accustomed to great constriction, and dilates afterwards with difficulty. It is obvious, that, to correct this vicious disposition, you must shew the child distant objects which will strongly engage his curiosity, and keep him at some distance from every thing he looks at.

The sensibility of the retina, on some occasions, rises to such excess, that the eye can scarcely bear the impression of the faintest light. *Nyctaclopes*, such is the name given to those affected with this disorder, distinguish objects amidst the deepest darkness; a few rays are sufficient to impress their organ.

It is related that an English gentleman, shut up in a dark dungeon, came gradually to distinguish all it contained: when he returned to the light of day, of which he had in some sort lost the habit, he could not endure its splendour, the edges of the pupil, before extremely dilated, became contracted to such a degree as entirely to efface the opening.

When, on the other hand, the retina has little sensibility, strong daylight is requiste to sight. This injury of vision, known by the name of *hemeralopia*[†], may be considered as the first step of total paralysis of the optic nerve, or *gutta serena*. It may arise from any thing that can impair the sensibility of the retina. Saint-Yves relates, in his work on diseases of the eyes, many cases of hemeralopia. The subjects were chiefly workmen employed, at the Hotel des Monnoies, in melting the metals. The inhabitants of the Northern regions, where the earth is covered with snow, great part of the year, become at an early age hemeralopes.

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[*] The Author means "scarcely divergent." T.

[†] I give to the words *nyctalopia* and *hemeralopia* the same meaning as all other writers down to Scarpa, who has pnblished the latest Treatise on diseases of the eyes. This acceptation is, however, a grammatical error, since of the two terms, *nyctalopia*, in its Greek roots, signifies an affection which takes away sight during the night, and *hemeralopia*, one in which it is lost during the day. It is accordingly in this sense that they are used by the father of Physic. I owe this remark to Dr. Roussille Chamseru, who has carefully verified the text of Hippocrates in the MSS. of the Imperial library.

Both contract this weakness, from their eyes being habitually fatigued by the splendour of too strong a light.

Finally, in order to the completion of the mechanism of vision, it is requisite that all parts of the eye be under certain conditions the want of which is more or less troublesome. It is especially necessary, that the membranes and the humours which the rays of light are to pass through, should be perfectly transparent. Thus, specks of the cornea, the closing of the pupil by the preservation of the membrane which stops that opening during the first months of the life of the fœtus; cataract, an affection which consists in the opacity of the crystalline lens or its capsule; the glaucoma, or defect of transparency in the vitreous humour, weaken or altogether destroy sight, by impeding the passage of the rays to the rétina. This membrane itself must be of tempered sensibility to be suitably affected by their contact. The choroid, the concavity of which it fills, must present a coating black enough to absorb the rays that pass through it. It is to the sensible decay of the dye of the choroid in advancing years, as much as to the collapsing, induration, and discolouring of different parts of the eye, and the impaired sensibility of the retina from long use, that we ascribe the confusion and weakness of sight in old people. The extreme delicacy of the eyes of *Albinos* proves equally the necessity of the absorption of light, by the black coating which covers the choroid.

The eyes are, of all the organs of sense, those which are the most developed in a new-born child.—They have then nearly the bulk which they are to retain during life. Hence it happens, that the countenance of children, whose eyes are proportionally larger, is seldom disagreeable, because it is chiefly in these organs, that physiognomy seeks expression. Might we not say, that if Nature sooner completes the organ of sight, it is because the changes which it produces on the rays of light, arising purely from a physical necessity, the perfection of the instrument was required for the exercise of the sense?

The eyes are not immoveable in the place they occupy. Drawn into very various motions, by four *recti* muscles, and two *oblique*, they direct themselves towards all objects of which we wish to take cognizance, and it is observed, that there is, between the muscles which move the two eyes, such a correspondence of action, that these organs turn at once the same way, and are directed, at once, towards the same object, in such a manner, that the visual axes are exactly parallel. It some times happens, that this harmony of motion is disturbed; and thence *squinting*; an affection, which depending, almost always, on the unequal force of the muscles of the eye, may be distinguished into as many species as there are muscles which can draw the globe of the eye into their direction, when from any cause, they become possessed of a predominating power. Buffon has further assigned, as a cause of squinting, the different aptitude of the eyes to be affected by light. According to this celebrated Naturalist, it may happen, that one of the eyes being originally of greater sensibility, the child will close the weaker to use the stronger, which is yet strengthened by exercise, whilst repose still weakens the one which remains in inaction. The examination of a great many young people, who had fallen under military conscription, and claimed exemption, on the score of infirmities, has shewn me that squinting is constantly connected with the unequal power of the eyes. Constantly, the inactive eye is the weakest, almost useless, and it was quite a matter of necessity that the diverging globe should be thus *neutralized*, else the image it would have sent to the brain, different from that which the sound eye gives, would have introduced confusion into the visual functions. The squinting eye, being inactive, falls by degrees into that state of debility, from default of exercise, which Brown has so well called indirect debility.

The sense of sight appears to me, much rather to deserve the name which J. J. Rousseau has given to that of smell, of sense of the imagination. Like that brilliant faculty of the soul, the sight, which furnishes us with ideas so rich and varied, is liable to betray us into many errors. It may be doubted, whether it gives the notion of distance, since the boy couched by Cheselden, conceived every thing he saw to touch his eye. It exposes us to false judgments on the form and size of objects; since, agreeably to the laws of optics, a square tower seen at a distance, appears to us round; and very lofty trees seen also very far off, seem no taller than the shrubs near us. A body, moving with great rapidity, appears to us motionless, &c. It is from the touch, that we gain the correction of these errors, which Condillac, in his Treatise on Sensation, has perhaps exaggerated.

CXX. The organ of sight, in different animals, varies according to the medium in which they live; thus, in birds which fly in the higher regions of the air, there is an additional and very remarkable eye lid, this is particularly the case with the eagle, which is thus enabled to look at the sun, and with night birds, whose very delicate eye it seems to protect from the effects of too strong a light. In birds, likewise, there is a copious secretion of tears, the medium in which they live causing a considerable evaporation. The greater part of fishes, on the contrary, have no moveable eyelid, and their eyes are not moistened by tears, as the water in which they are immersed, answers the same purpose. In some fishes, however, the eyes are smeared with an unctuous substance calculated to prevent the action of the water on the organ.

The globe of the eye in birds, is remarkable by the convexity of the cornea which is, sometimes, a complete hemisphere, hence it possesses a considerable power of refraction. This power of refraction, appears to be very weak in fishes, the fore part of their eyes being very much flattened; but the water in which they live made it unnecessary, that they should have an aqueous humour, for, the density of this fluid being nearly the same as that of water, it would not have produced any refraction: besides, being, in sea fish, of inferior density to that of salt water, it would have broken the rays of light, by making them diverge from the perpendicular. In fact, the refractive power of a medium is never but a relative quantity; the degree of refraction is not determined by the density of the medium, but by the difference of density between it and the medium that is next to it. To make up for the flatness of the cornea occasioned by the small quantity, or even by the absence, of aqueous humour, fishes have a very dense and spherical crystalline humour, the spherical part of which forms a part of a small sphere.

The eyes of birds, whose cornea is thrust out by a very copious aqueous humour, possess, in consequence of the presence of this fluid, a very considerable power of refraction; the air, in the higher regions of the air, owing its extreme rarefaction, being but little calculated to approximate the rays of light.

The pupil admits of greater dilatation in the cat, in the owl, in night birds, and in general in all animals that see in the dark. The sensibility of the retina appears, likewise, greater in those animals; several of them appear incommoded by the light of day, and never pursue their prey, but in the most obscure darkness.

The crystalline humour of several aquatic fowls, as the cormorants, is spherical like that of fishes, and this is not, as will be mentioned hereafter, the only peculiarity of structure in these kind of amphibious animals. Lastly, the choroid of some animals, more easily separated into two distint laminæ, than that of man, presents, at the bottom of the eye, instead of a darkish, uniformly diffused coating, a pretty extensive spot of various colours, and in some, most beautiful and brilliant. It is not easy to say what is the use of this coloured spot, known by the name of *tapetum*.

The rays of light, reflected by this opaque substance, must, in passing through the eye, cross those which are entering at the same time; they must, consequently, prevent distinct vision, or at least impair the impression, in a manner which it is impossible to determine. It has been said, that the lower animals, provided with less perfect and often less numerous senses than those of man, must have different ideas of the universe; is it not, likewise, probable, that in consequence of the indistinct vision occasioned by the reflection from the tapetum, they may entertain erroneous and exaggerated notions of the power of man? And notwithstanding the power granted to man by the Creator over the lower animals, as we are told in the book of Genesis, is it probable that those which Nature has gifted with prodigious strength or with offensive weapons, would obey the Lord of the creation, if they saw him in his feeble and destitute condition, in a word, such as he is?

The head of insects with numerous eyes, is joined to their body, and moves along with it; their existence is, besides, so frail, that it was requisite that nature should furnish them abundantly with the means of seeing those objects which may be injurious to them. We shall not enter, any farther, into these remarks relative to the differences in the organ of sight, in the various kinds of animals. More ample details on this subject belong, in an especial manner, to comparative anatomy.

CXXI. *Of the organ of hearing. Of sound.* Sound is not, like light, a body having a distinct existence; we give the name of sound to a sensation which we experience, whenever the vibrations of an elastic body strike our ears. All bodies are capable of producing it, provided their molecules are susceptible of a certain degree of re-action and resistance. When a sonorous body is struck, its integrant particles experience a sudden concussion, are displaced and oscillate with more or less rapidity, This tremulous motion is communicated to the bodies applied to its surface; if we lay our hand on a bell that has been struck by its clapper, we feel a certain degree of this trembling. The air, which envelops the sonorous body, receives and transmits its vibrations with the more effect from being more elastic. Hence, it is observed that, cæteris paribus, the voice is heard, at a greater distance in winter, when the air is dry and condensed by the cold.

The sonorous rays are merely series of particles of air along which the vibration is transmitted, from the sonorous body, to the ear which perceives the noise occasioned by its percussion. These molecules participate in the vibrations which are communicated to them; they change their form and situation, in proportion as they are nearer to the body that is struck, and vice versâ; for, sound becomes weaker, in proportion to the increase of distance. But this oscillatory motion of the aerial molecules, should be well distinguished from that by which the atmosphere, agitated by the winds, is transported and changes its situation. And in the same manner as the balance of a pendulum moves incessantly within the same limits, so, this oscillatory motion affects the molecules of the air within the space which they occupy, so that they move to and fro during the presence or the absence of the vibration. The atmospherical air, when set in motion, in a considerable mass at a time, produces no sound, unless in its course, it meets with a body which vibrates from the percussion which it experiences.

The force of sound depends, entirely, on the extent of the vibrations experienced by the molecules of the sonorous body. In a large bell struck violently, the agitation of the molecules is such, that they are transmitted to considerable distances, and that the form of the body is evidently changed by it. Acute or grave sounds are produced by the greater or smaller number of vibrations, in a given time, and the vibrations will be more numerous, the smaller the length and diameter of the body. Two catgut strings, of the same length and thickness, and with an equal degree of tension, will vibrate, an equal number of times, in a given time, and produce the same sound. This, in music, is called *unison.* If one of the strings is shortened by one half, it vibrates as often again as the other, and gives out a sound more acute, or higher by one *octave.* The same result may be obtained by reducing the string one half of its original thickness, without taking from its length. The vibrations will, in the same manner, be accelerated, by giving a greater degree of tension to the sonorous cord. The difference of the sounds produced by a bass, a harp, or any other stringed instrument, depends on the unequal tension, length, and size of the strings.

This division of the elementary sound is an act of the understanding which distinguishes, in a noise apparently monotonous, innumerable varieties, and shades expressed by signs of convention. But in the same manner as light, refracted by a prism, presents innumerable intermediate shades, between the seven primitive colours, and as the transition is gradual, from the one to the other of these colours: so, the division of the primitive sound into seven tones expressed by notes, is not absolute, and there are a number of intermediate sounds which augment or diminish their value, &c.

Sound has, therefore, been analysed as well as light; the use of the ear, with regard to sound, corresponds to that of the prism with regard to light, and the modifications of which sound is capable, are as numerous and as various, as the shades between the primitive colours.

Sound is propogated with less velocity than light. The report of a cannon fired at a distance, is heard only a moment after the eye has perceived the flash of the explosion. Its rays diverge and are reflected, like those of light, when they meet with an obstacle at an angle equal to that of incidence. The force of sound, like that of light, may be increased by collecting and concentrating its rays. The sonorous rays which strike a hard and elastic body, when reflected by it, impart to it a vibratory motion, giving rise to a secondary sound which increases the force of the primitive sound.

When these secondary sounds, produced by the percussion of a body at a certain distance, reach the ear, they give rise to what is called an echo. Who is unacquainted with the ingenious allegory, by which its nature is expressed in ancient mythology, in which echo was called, daughter of the air and of the earth?

CXXII. *Of the organ and mechanism of hearing.* The organ of hearing, in man, consists of three very distinct parts; the one, placed externally, is intended to collect and to transmit the sonorous rays which are modified in passing along an intermediate cavity, between the external and internal ear. It is within the cavities of this third part of the organ, excavated in the substance of the petrous portion of the bone, that the nerve destined to the perception of sound, exclusively resides. The external ear and the meatus auditorius externus may be compared to an acoustic trumpet, the broad part of which, represented by the concha, collects the sonorous rays which are afterwards transmitted along the contracted part, represented by the meatus externus. The concha contains several prominences separated by corresponding depressions; its concave part is not wholly turned outward, in those who have not laid their ears flat against the side of the head, by tight bandages, it is turned slightly forward, and this arrangement, favourable to the collecting of sound, is particularly remarkable in savages, whose hearing, it is well known, is remarkably delicate. The base of the concha consists of a fibro cartilaginous substance, thin, elastic, calculated to reflect sounds and to increase their strength and intensity, by the vibrations to which it is liable. This cartilage is covered by a very thin skin, under which no fat is collected that could impair its elasticity; these prominences are connected together by small muscles; these may relax it, by drawing the projections together, and thus place it in unison with the acute or grave sounds. These small muscles within the external ear, as the musculi helicis major and minor; the tragicus and antitragicus and the transversus auris, are like the muscles on the outer part of the ear, stronger and more marked in timid animals with long ears. In the hare, the fibres of these muscles are most distinctly marked, their action is most apparent in this feeble and fearful animal which has no resource but in flight, against the dangers which incessantly threaten his existence, and which required that he should receive early intimation of the approach of danger; hence hares have the power of making their ears assume various forms, of shaping them into more advantageous trumpets, of moving them, in every direction, of directing them towards the quarter from which the noise proceeds, so as to meet the sounds and collect the slightest.

The form of the external ear, is not sufficiently advantageous in man, whatever Boerhaave may have said to the contrary, to enable all the sonorous rays, which in striking against it, are reflected at an angle equal to that of their incidence, to be directed towards the meatus auditorius externus. United, for the most part, into a single fasciculus and directed towards the concha, they penetrate into the meatus auditorius externus, and the tremulous motions which they excite in its osso cartilaginous parietes contribute to increase their force. On reaching the bottom of the meatus, they strike against the membrana tympani, a thin and transparent septum stretched between the bottom of the meatus and the cavity in which the small bones of the ear are lodged. These small bones form a chain of bone which crosses the tympanum from without inward, and which extends from the membrana tympani to that which connects the base of the stapes to the edge of the fenestra ovalis.

An elastic air, continually renewed by the Eustachian tube, fills the cavity of the tympanum; small muscles attached to the malleus and stapes move these bones or relax the membranes to which they are attached, and thus institute a due relation between the organ of hearing and the sounds which strike it. It will be easily conceived, that the relaxation of the membrana tympani, effected by the action of the anterior muscle of the malleus, must weaken acute sounds, while the tension of the same membrane, by the internal muscles of the same bone, must increase the force of the grave sounds. In the same manner, as the eye by the contraction or dilatation of the pupil, accommodates itself to the light, so as to admit a greater or smaller number of its rays, according to the impression which they produce, so by the relaxation or tension of the membrane of the tympanum, or of the fenestra ovalis, the ear reduces or increases the strength of sounds whose violence would affect its sensibility, in a painful manner, or whose impression would be insufficient. The iris and the muscles of the stapes and of the malleus are, therefore, the regulators of the auditory and visual impression; there is as close a sympathetic connexion between these muscles and the auditory nerve, as between the iris and the retina. The air which fills the tympanum is the true vehicle of sound; this air diffuses itself over the mastoid cells, the use of which is to augment the dimensions of the tympanum, and the force and extent of the vibrations which the air experiences within it.

These vibrations, transmitted by the membrana tympani, are communicated to those membranes which cover the fenestra ovalis and the fenestra rotunda, then, by means of these, to the fluid which fills the different cavities of the internal ear, and in which lie the soft and delicate filaments of the auditory nerve or of the portio mollis of the seventh pair.

The agitation of the fluid affects these nerves and determines the sensation of grave or acute sounds, according as they are slower or more rapid. It appears, that the diversity of sounds should rather be attributed to the more or less rapid oscillations, and to the undulations of the lymph of Cotunni, than to the impressions on filaments, of different lengths, of the auditory nerve. These nervous filaments are too soft and too slender to be traced to their extreme terminations. It is, however, probable, that the various forms of the internal ear (the *semi-circular* canals, the *vestibule*, and the *cochlea*), have something to do with the diversity of sounds. It must also be observed, that the cavities of the ear are contained in a bony part, harder than any other substance of the same kind, and well fitted to maintain, or even to augment by the re-action of which it is capable, the force of the sonorous rays.

The essential part of the organ of hearing, that which appears exclusively employed in receiving the sensation of sounds is, doubtless, that which exists in all animals endowed with the faculty of hearing. This part is the soft pulp of the auditory nerve, floating in the midst of a gelatinous fluid, contained in a thin and elastic membranous cavity. It is found in all animals, from man to the sepiæ. In no animal lower in the scale of animation, has an organ of hearing been met with, although some of these inferior animals do not seem to be absolutely destitute of that organ. This gelatinous pulp is, in the lobster, contained in a hard and horny covering. In animals of a higher order, its internal part is divided into various bony cavities, In birds, there is interposed a cavity, between that which contains the nerve of hearing and the outer part of the head; in man and in quadrupeds, the organ of hearing is very complicated; it is enclosed in an osseous cavity, extremely hard, situated at a considerable depth, and separated from the outer part of the head, by a cavity and a canal along which the sonorous rays are transmitted, after having been collected into fasciculi by trumpets situated on the outside.

This kind of natural analysis of the organ of hearing, is well calculated to give accurate notions on the nature and importance of the functions fulfilled by each of its parts. But in the investigation of the uses and of the relative importance of the auditory apparatus, morbid anatomy furnishes data of an equal value with those obtained from comparative anatomy.

CXXIII. The external ear may be removed, with impunity, in man, and even in animals in which its form is more advantageous; the hearing is, at first impaired, but at the end of a few days, recovers its wonted delicacy. The complete obliteration of the meatus auditorious externus, is attended with complete deafness. It is not essentially necessary for the mechanism of hearing, that the membrana tympani should be whole; persons in whom it has been accidentally ruptured, can force out smoke at their ears, without losing the power of hearing; it may be conceived, however, that if instead of having merely a small opening that would not prevent its receiving the impression of the sonorous rays, nor its being acted upon by the handle of the malleus, the membrana tympani were almost entirely destroyed, deafness would be the almost unavoidable consequence. If, in consequencce of the obstruction of the Eustachian tube, the air in the tympanum is not renewed, it loses its elasticity and combines with the mucus within the tympanum, The cavity of the tympanum is then, in the same condition as an exhausted receiver, in which the sonorous rays are transmitted with difficulty. It has been thought, that the use of the Eustachian tube was, not only to renew the air contained in the tympanum, but also to transmit the sonorous rays into that cavity. In listening attentively, we slightly open our mouth; in order, it is said, that the sound may pass from this cavity into the pharynx and thence reach the organ of hearing, This explanation is far from satisfactory, for, the obliteration of the meatus auditorius externus is attended with complete deafness, which would not happen, if the Eustachian tubes transmitted the sonorous rays. When a man listens attentively, and with his mouth open, the condyles of the lower jaw, situated in front of the external auditory meatus, being depressed and brought forward, the openings are evidently enlarged, as may be ascertained by putting the little finger into one's ear, at the moment of depressing the lower jaw. The luxation of the small bones of the ear, or even their complete destruction does not occasion deafness, the only consequence is a confusion in the perception of sounds. When, however, the stapes, the base of which rests on the greatest part of the fenestra ovalis, or when the thin membrane which closes the fenestra ovalis, or when that which closes the fenestra rotunda is destroyed, deafness takes place, in consequence of the escape of the fluid which fills the cavities in which auditory nerve is distributed.

The existence of this fluid appears essential to the mechanism of hearing, either from its keeping the nerves in the soft and moist state required for the purpose of sensation, or from its transmitting to them, the undulatory motion with which it is agitated.

The deafness of old people, which, according to authors, depends on the impaired sensibility of the nerves, whose excitability has been exhausted by impressions too frequently repeated, appears, sometimes, to be occasioned by a deficiency of this humour, and by the want of moisture in the internal cavities of the ear. During the severe winter of 1798, Professor Pinel opened, at the Hospital of Salpêtriere, the skull of several women who died at a very advanced age, and who had been deaf for several years. The cavities of the internal ear were found quite empty; they contained an icicle in younger subjects who had possessed the power of hearing.

Deafness may, likewise, be produced by a palsy of the portio mollis of the seventh pair, or by a morbid condition of the part of brain from which this nerve arises. The mechanical explanation applied by Willis to the anomalous affections of the organ of hearing, is inadmissible, those in which that organ is sensible only to the impression of weak or strong sounds acting together or separately.

This author relates the case of a woman who could not hear, unless a great noise was made near her, either by beating a drum or by ringing a bell, because, says he, under such circumstances, these loud noises determine in the membrana tympani, which he supposes in a state of relaxation, the degree of tension required to enable it to vibrate under the impression of weaker sounds. This membrane, to present greater resistance, must be put on the stretch by the internal muscle of the malleus, or by its own contraction. The total absence of muscular fibres in the membrani tympani, in man, renders very doubtful this spontaneous contraction. Mr. Home, however, has just ascertained that the membrana tympani of the elephant is muscular and contractile. Admitting all these suppositions, we only substitute one difficulty for another, and it remains to be shewn, why the more powerful sounds merely increase the tone of the membrana tympani; why they do not become objects of perception of the organ of hearing, though they might be expected to render us insensible to the perception of weaker sounds.

CXXIV. *Of odours.* Chemists have long thought that the odoriferous part of bodies formed a peculiar principle, distinct from all the other substances entering into their composition; they gave it the name of *aroma*; M. Fourcroy, however, has clearly shewn, that this pretended element consisted merely of minute particles of bodies, detached by heat and dissolved in the atmosphere, which becomes loaded with them and conveys them to the olfactory organs. According to this theory, all bodies are odoriferous, since caloric may sublimate some of the particles of those which are least volatile. Linnæus and Lorry had endeavoured to class odours, according to the sensations which they produce*; M. Fourcroy has been guided by the chemical nature of substances; but however advantageous this last classification may be, it is difficult to include in it, the infinitely varied odours which exhale from substances of all kinds, and it is perhaps as difficult to arrange them in classes, as the bodies from which they are produced.

This being laid down on the nature of odours, it is next explained, why the atmosphere becomes loaded with the greater quantity, the warmer and the more moist it is. We know, that in a flower garden, the air is at no time more loaded with fragrant odours, and the smell is never the source of greater enjoyment, than in the morning, when the dew is evaporating by the rays of the sun. It is, likewise, easily understood, why the most pungent smells, generally evaporate very readily, as ether, alcohol, the spirituous tinctures and essential volatile oils.

CXXV. *Of the organ of smell.* The nasal fossæ, within which this organ is situated, are two cavities in the depth of the face and extending backward into other cavities, called frontal, ethmoideal, sphenoideal, palatine, and maxillary sinuses.

A pretty thick mucous membrane, always moist, and in the tissue of which, the olfactory nerves and a considerable number of other nerves and vessels are distributed, lines the nostrils and extends into the sinuses which communicate with them and covers their parietes, throughout their windings and prominences. This membrane, called *pituitary*, is soft and fungous and is the organ which secretes the mucus of the nose; it is thicker over the turbinated bones which lie within the olfactory cavities; it grows thinner and firmer, in the different sinuses.

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* Linnæus admits seven classes of odours; 1st class, *ambrosiac* odours, those of the rose and of musk belong to this class, they are characterized by their tenacity: 2nd, *fragrant*; for example, the lily, the saffron, and jasmine; they fly off readily; 3rd, *aromatic*, as the smell of the laurel; 4th, *aliaceous*, approaching to that of garlic: 5th, *fetid*, as that valerian and fungi. 6th *virous*, as of poppies and opium: 7th, *nauseous* as that of gourds, melons, cucumbers, and, in general, all cucurbitaceous plants.

Lorry admits only five kinds of odours, *camphorated*, *narcotic*, *ethereal*, *volatile acid*, and *alkaline*.

M. Fourcroy admits the *mucous* aroma, belonging to plants improperly termed inodorous. *Oily and fugacious*, *oily and volatile*, *acid and hydro-sulphureous*.

The smell appears more delicate in proportion as the nasal fossæ being more capacious, the pituitary membrane covers a greater space. The soft and moist condition of this membrane is, likewise, essentially necessary to the perfection of this sense. In the dog, and in all animals which have a very exquisite sense of smell, the frontal, ethmoideal, sphenoidal, palatine and maxillary sinuses, are prodigiously capacious, and the parietes of the skull are, in great measure, hollowed by these different parts of the olfactory apparatus; the turbinated bones are, likewise, very prominent in them, and the grooves between them, very deep; lastly, the nerves of the first pair are large in proportion. Among the animals possessed of great delicacy of smell, few are more remarkable than the hog. This impure animal, accustomed to live in the most offensive smells, and in the most disgusting filth, has, however, so very nice a smell, that it can detect certain roots, though buried in the earth at a considerable depth. In some countries, this quality is turned to advantage, and swine are employed in looking for trufles. The animal is taken to those places where they are suspected to be, turns up the earth in which they buried and would feed on them greedily, if the herdsman satisfied with this indication, did not drive them away from this substance intended for more delicate palates.

CXXVI. *Of the sensation of odours.* Do the nerves of the fisrt pair alone give to the pituitary membrane, the power of receiving the impression of smell, and do the numerous filaments of the fifth pair, merely impart to it the general sensibility belonging to other parts? This question appears to require an answer in the affirmative. The pituitary membrane, in fact, possesses, two modes of sensibility, perfectly distinct, since the one of the two may be almost completely destroyed and the other considerably increased. Thus, in violent catarrh, the sensibility of the part, as far as relates to the touch, is very acute, since the pituitary membrane is affected with pain, while the patient is insensible to the strongest smells.

It seems probable, that the olfactory nerves do not extend into the sinuses, and that these improve the sense of smell, merely by retaining, for a longer space of time, a considerable mass of air loaded with odoriferous particles. I have known detergent injections, strongly scented, thrown into the antrum highmorianum by a fistula in the alveolar processes, produce no sensation of smell. A phial filled with a spirituous liquor having been applied to a fistula in the frontal sinuses, gave no impression to the patient. The true seat of the sense of smell is at the most elevated part of the nostrils, which the nose covers over in the form of a capital. There the pituitary membrane is moister, receives into its tissue the numerous filaments of the first pair of nerves, which arising by two roots from the anterior lobe of the brain, and from the fissure which separates it from the posterior lobe, passes from the cranium, through the openings of the cribriform plate of the ethmoid bone, and terminates forming, by the expansion of its filaments, a kind of parenchymatous tissue not easily distinguished from that of the membrane. The olfactory papillæ would soon be destroyed by the contact of the atmospherical air, if they were not covered over by the mucus of the nose. The use of this mucus is, not merely to preserve the extremities of the nerves, in a sentient state, by preventing them from becoming dry, but, likewise, to lessen the too strong impression that would arise from the immediate contact of the odoriferous particles. It perhaps even combines with the odours, and these affect the olfactory organs, only when dissolved in mucus, as the food in saliva.

As the air is the vehicle of odours, these affect the pituitary membrane, only when we inhale it into the nostrils. Hence, when any odour is grateful to us, we take in short and frequent inspirations, that the whole of the air, which is received into the lungs, may pass through the nasal fossæ. We, on the contrary, breathe through the mouth, or we suspend respiration altogether, when smells are disagreeable to us.

The sense of smell, like all the other senses, is readily impressed in children, though the nasal fossæ are, in them, much contracted, and though the sinuses are not yet formed. The general increase of sensibility, at this period of life, makes up for the imperfect state of the organization, and it is, in this respect, with the nasal fossæ, as with the auditory apparatus, of which an important part, the meatus externus, is then not completely evolved. The sense of smell is perfected by the loss of some of the other senses; every body, for example, knows the history of the blind man whom that organ enabled to judge of the continence of his daughter; it becomes blunted by the application of strong and pungent odours. Thus, snuff changes the quality of the mucus secreted by the membrane of the nose, alters its tissue, drys its nerves, and, in the course of time, impairs their sensibility.

The shortness of the distance between the origin of the olfactory nerves, in the brain, and their termination in the nasal fossæ, render very prompt and easy the transmission of the impressions which they experience. This vicinity to the brain, induces us to apply to those nerves, stimulants calculated to rouse the sensibility, when life is suspended, as in fainting and asphyxia. The sympathetic connexions, between the pituitary membrane and the diaphragm, account for the good effects of sternutatories, in cases of apparent death.

CXXVII. *Of flavours.* Flavours are no less varied and no less numerous than odours; and it is as difficult to reduce them to general classes connected by analogies and including the whole.* Besides, there exists no element of flavour, any more than an odoriferous principle. The flavour of fruits alters, as they ripen, and appears to depend on the inward composition of bodies, on their peculiar nature, rather than on the form of their molecules, since crystals of the same figure, but belonging to different salts, do not produce similar sensations.

To affect the organ of taste, a body should be soluble at the ordinary temperature of the saliva; all insoluble substances are insipid, and one might apply to the organ of taste, this celebrated axiom in chemistry; *corpora non agunt nisi soluta.* If there is a complete absence of saliva, and if the body that is chewed is altogether without moisture, it will affect the parched tongue, only by its tactile, and not at all by its gustatory qualities. The substances which have most flavour, are those which yield most readily to chemical combinations and decompositions, as acids, alkalis and neutral salts. When, in affections of the digestive organs, the tongue is covered with a mucous or whitish fur, or of a yellowish or bilious colour, we have only incorrect ideas of flavours; the thinner or thicker coating prevents the immediate contact of the sapid particles; when they act, besides, on the nervous papillæ, the impression which they produce is lost in that occasioned by the morbid contents of the stomach; hence every aliment appears bitter, while the bilious disposition exists, and insipid, in those diseases in which the mucous elements prevail.

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* This has been attempted, though with indifferent success, by Boerhaave, Haller, and Linnæus. *Acid, sweet, bitter, acrid, saltish, alkaline, vinous, spirituous, aromatic, and acerb* were the terms employed by those physicians, to express the general characters of flavours.

CXXVIII. *Of the sense of taste.* No sense is so much akin to that of the touch, or resembles it more. The surface of the organ of taste differs from the common integuments, only in this respect, that the chorion, the mucous body and the epidermis which envelop the fleshy part of the tongue are softer, thinner, and receive a greater quantity of nerves and vessels, and are habitually moistened by the saliva and by the mucus, secreted by the mucous glands contained in their substance. These mucous cryptæ, and the nerves of the cutaneous covering of the tongue, raise the very thin epidermis which covers its upper furface, and form a number of papillæ distinguished, by their form, into *fungous*, *conical*, and *villous*. With the exception of the first kind, these small prominences are formed by the extremities of nerves surrounded by blood vessels which give to these papillæ the power of becoming turgid and prominent, and of being affected with a kind of erection, when we eat highly seasoned food, or when we long for a savoury dish. The fungous papillæ are mostly situated at the remotest part of the upper surface of the tongue, towards its root, where it forms a part of the isthmus faucium. The pressure with which they are affected by the alimentary bolus, in its passage from the mouth into the pharynx, squeezes out the mucus which lubricates the edges of the aperture, and serves to promote its passage: these mucous follicles, fulfil, in this respect, the same office, as the amygdalæ.

The upper surface of the tongue is the seat of taste: it is undeniable, however, that the lips, the gums, the membrane lining the arch of the palate, and the velum palati, may be affected by the impression of certain flavours.

It is observed, in the different animals, that the organ of taste is more perfect, according as the nerves of the tongue are larger, its skin thinner and moister, its tissue more flexible, its surface more extensive, its motions easier and more varied. Hence, the bone in the tongue of birds, by diminishing its flexibility, the osseous scales of the swan's tongue, by reducing the extent of the sentient surface; the adhesion of the tongue to the jaws, in frogs, in the salamander and in the crocodile, by preventing freedom of motion, render in these animals, the sense of taste duller and less calculated to feel the impression of sapid bodies, than in man, and the other mammiferous animals. Man would, probably, excel all the other animals, in delicacy of taste, if he did not, at an early period, impair its sensibility, by strong drinks, and by the use of spices, and of all the luxuries that are daily brought to our tables. The quadrupeds, whose tongue is covered by a rougher skin, discover better than we can, by the sense of taste, poisonous, or noxious substances. We know, that in the variety of plants which cover the face of the earth, herbivorous animals select a certain number of plants suited to their nature, and uniformly reject those which would be injurious to them.

CXXIX. Is the lingual branch of the fifth pair of nerves, alone subservient to the sense of taste? Are not the ninth pair (almost wholly distributed in the tissue of the tongue), and the glosso pharyngeal branch of the eighth, likewise subservient to this function? Most anatomists, since Galen, have thought that the eighth and ninth pair supplied the tongue with its nerves of motion, and that it received from the fifth, its nerves of sensation. Several filaments, however, of the great hypoglossal nerve, may be traced into the nervous papillæ of the tongue. This nerve is larger than the lingual, and is more exclusively distributed to this organ than the fifth pair, to which the other nerve belongs. Hevermann states, that he knew a case, in which the sense of taste was lost from the division of the nerve of the ninth pair, in removing a schirrous gland. This case, however, appears to me a very suspicious one. The patient might still have tasted, by means of the lingual nerve, and the sense would only have been weakened. The division of one of the nerves of the ninth pair could render

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* Especially the anterior part of the palatine membrane. The naso-palatine nerve, discovered by Scarpa, after arising from the ganglion of Mekel, and going for a pretty considerable distance into the nasal fossæ, terminates in that thick and rugous portion of the palatine membrane situated behind the upper incisors, and with which the tip of the tongue is in such frequent contact.

insensible, only that half of the tongue to which it is distributed, the other half would continue fully to possess the faculty of taste.

The application of metals to the different nervous filaments distributed to the tongue, ought to inform us of their different uses, if, as Humboldt suspects, the galvanic excitement of the nerves of motion, alone produces contractions. To ascertain the truth of this conjecture, I placed a plate of zinc within the skull, under the trunk of the nerve of the fifth pair, in a dog that had been killed a few minutes before, and that still retained its warmth; the muscles of the tongue, under which a piece of silver was placed, quivered very slightly; those of the forehead and temples in contact with the same metal, experienced very sensible contractions, whenever a communication was made, by means of an iron rod. This experiment shewed, that the lingual branch of this nerve was, almost solely, subservient to the sensation of taste, which agrees with the opinion of most physiologists, and the same inference may be drawn from the anatomical knowledge of the situation of this nerve which, almost entirely, terminates in the papillæ of the membrane of the tongue, and sends very few filaments to the muscles of that organ. But though the galvanic irritation applied to the hypoglossal nerve affected the whole tongue, in a convulsive manner, I did not think myself justified to infer, that this nerve was solely destined to perform its motions; as this nervous trunk might, in this part of the body, as it does in others, contain filaments both of sensation and motion.

The tongue, though an azygous organ, is formed of parts completely symmetrical; there are, on each side, four muscles *(stylo, hyo, genio, glosso and lingual)*; three nerves *(lingual, glosso-pharyngeal, and hypoglossal)*; a ranine artery and vein; and a set of lymphatic vessels precisely alike. All these parts, by their union, form a fleshy body of a close texture and not easily unravelled, similar to that of the ventricles of the heart, endowed with a considerable degree of mobility, in consequence of the numerous vessels and nerves entering into its substance. If we compare their number and size with the small bulk of the organ, it will be readily understood, that, as no part of the body can execute more frequent, more extensive, and more varied motions, so no one receives more vessels and nerves. A middle line separates and marks the limits of the two halves of the tongue, which anatomically and physiologically considered, appears formed of two distinct organs in juxta-position.

This independance of the two parts of the tongue is confirmed by the phenomena of disease; in hemiplegia, the side of the tongue corresponding to the half of the body that is paralyzed, loses, likewise, the power of motion; the other retains its mobility, and draws the tongue towards that side. In carcinoma of the tongue, one side remains unaffected by the affection which destroys the other half; lastly, the arteries and nerves of the left side rarely anastomose with those on the right; injections forced along one of the ranine arteries, fill only the corresponding half of the organ; &c.

CXXX. *Of the touch.* No part of the surface of our body is exposed to receive the touch of a foreign body, without our being speedily informed of it. If the organs of sight, of hearing, of smell, and of taste, occupy only limited spaces, touch resides in all the other parts and effectually watches over our preservation. The touch, distributed over the whole surface, appears to be the elementary sense, and all the others are only modifications of it, accommodated to certain properties of bodies. All that is not light, sound, smell, or flavour, is appreciated by the touch, which thus instructs us in the greater part of the qualities of bodies which it concerns us to know, as their temperature, their consistence, their state of dryness, or humidity, their figure, their size, their distance, &c. It corrects the errors of the sight and of all the other senses, of which it may justly be called the regulator, and it furnishes us with the most exact and distinct ideas.

The touch, of which some authors have sought to consecrate the excellence, by giving it the name of the geometrical sense, is not, however, safe from all mistake. Whilst it is employed on the geometrical properties, derived from space, and that it appreciates the length, the breadth, the thickness, the form of bodies, it transmits to the intellect, rigourous and mathematical results; but the ideas we acquire, by its means, on the temperature of bodies are far from being equally precise. For, if you have just touched ice, another body colder than yours, will appear warm. It is for this reason, that subterraneous places appear warm to us during winter. They have kept their temperature whilst all things else have changed theirs; and as we judge of the heat of an object by its relation not only to our own, but also to that of other bodies and of the air about us, we find the same places warm; which had appeared cold to us, in the middle of summer.

The densest bodies being the best conductors of heat*, marble, metals, &c. appear colder to us than they really are, because they carry it off so rapidly. Marble and metals, when polished, appear still colder, because, as they touch the skin in many more points at once, they effect this abstraction more effectually. Every one knows the experiment of placing a little ball between the two fingers crossed, and producing the sensation of two different balls.

CXXXI. *Of the integuments.* The general covering of the whole body is the organ of touch, which resides in the skin properly so called. The cellular tissue which connects together all our parts, forms over the whole body, a layer varying in thickness, which covers it, in every part; it is called *panniculus adiposus.* As it approaches the surface, its laminæ are more condensed, are in more immediate contact with each other, and are no longer separated by adeps. It is by the closer juxta position of the laminæ of the cellular tissue, that the skin or dermis is formed, a dense and elastic membrane, into which numerous vessels, of all kinds, are distributed, and into which so great a quantity of nerves terminate, that the ancients did not hesitate to consider the skin as purely nervous.

In certain parts of the body, a very thin muscular plane separates the skin from the panniculus adiposus. This kind of panniculus carnosus envelops, almost entirely, the body of some animals; its contractions wrinkle their skin covered with hairs, these rise, vibrate, and thus are cleared of the dust and dirt which may have gathered on them. It is by means of a cutaneous muscle, of very complex structure, that the hedge hog is enabled to coil himself up,

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[*] Woolly substances, &c. all felts, of which the crossing hairs confine, in some sort, a great quantity of air, a fluid which, from its gazeous state, is a very bad conductor of heat, retain heat well;—and, of equal thickness, a stuff of fine wool, of which the hairs are more separated, the tissue softer, will be warmer than a stuff of coarse wool, of which the threads, too close, form a dense body, through which cold, as well as heat, will pass with ease. It is by thus confining a certain mass of air, that snow keeps the soil it covers, in a mild temperature, and preserves plants from the injury of excessive cold: a physical truth which is found figuratively expressed, in the words of the Psalmist "*Et dedit illi nivem tanquam vestimentum.*"

and to present to his enemy a surface studded with sharp points: only a few scattered rudiments of an analogous structure, are to be met with in the human body; the occipito frontalis, the corrugator supercilii, several muscles of the face, the platysma myoides, the palmaris cutaneous may be considered as forming part of this muscle. We may even include the cremaster, whose expanded fibres, surrounded by the dartos, have misled some anatomists to such a degree, that they have admitted the existence of a muscular texture in the latter. These fibres of the cremaster, produce distinct motions in the skin of the scrotum, wrinkle it, in a transverse direction, and, at the same time, bring up the testicles. The platysma myoides acts, likewise, on the skin of the neck; lastly, the occipito-frontalis, in some men, performs so distinct a motion of the hairy scalp, as to throw off a hat, a cap, or any other covering that may be on the head. One may compare to the panniculus carnosus, the muscular coat of the digestive tube, situated, throughout its whole length, below the mucous membrane, which is merely a prolongation of the skin modified and softened.

But if, in man, the subcutaneous muscle, from its imperfect state, answers purposes only of secondary importance, the layer of cellular adipose substance, extended under the skin, gives to the latter its tension, its whiteness, its polish, its suppleness, favours its applying itself to tangible objects and thus renders the touch more delicate. Too hard or wrinkled a skin would have applied itself in a very incomplete manner, to bodies of a small size, and would not readily have accommodated itself to the small irregularities of those of inconsiderable bulk. Hence the pulp of the fingers, which is the seat of a more delicate touch, is furnished with a kind of adipose cushion supported by the nails, ready to be applied to polished surfaces, and to discover their slightest asperities. I have observed the sense of touch to be very imperfect, in men wasted by marasmus, and whose hard, dry, and wrinkled skin adheres, in certain situations, to the subjacent parts.

The chemical analysis of the cutaneous tissue shews, that it does not exactly resemble that of the cellular and membranous tissue; it is gelatino-fibrous, and, with regard to its structure and to its share of contractility, it occupies a medium, between the cellular tissues and the muscular flesh. There arise, from the surface of the skin, innumerable small papillæ, fungous, conical, pointed, obtuse and variously shaped, in the different parts of the body. These papillæ are merely the pulpous extremities of the nerves which terminate into them, and around which there are distributed vascular tissues of the utmost minuteness. The papillæ of the skin, which are more distinct in the fingers and lips than elsewhere, swell, when irritated, elevate, in a manner, the epidermis, and this kind of erection, which is useful when we wish to touch a substance with great precision, may be excited by friction or by moderate heat.

The nervous or sentient surface of the skin is covered with a mucous coating, colourless in Europeans, of dark colour, from the effects of light, among the natives of southern climates; of a gelatinous nature, destined to maintain the papillæ in that state of moisture and softness favourable to the touch. This mucilaginous layer, known under the name of *rete mucosum* of Malpighi, seems to contain the principle which causes the variety of colour in the skin of different nations, as will be observed, in speaking of the varieties of the human species.

The reticular state of the rete mucosum may be explained in two ways; a thin and gelatinous layer, extended on the papillar surface of the skin, is perforated, at each nervous papilla: and if it were possible to coagulate or to detach this coating, we should have a real sieve, or reticulated mesh work, with a perforation at every point, corresponding to a cutaneous papilla. The sanguineous and lymphatic capillaries, which surround the nervous papillæ, form, besides, by their connexions, a net-work, the meshes of which are very minute and adhere to the epidermis, by a multitude of small vascular filaments that insinuate themselves between the scales of this last envelope.

The skin would be unable to perform its functions, if an outer, thin, and transparent membrane, the *epidermis*, did not prevent it from being over dried. This superficial covering is quite insensible, no nerves and no vessels, of any kind, are found in it, and even in the present state of the science, we do not understand how it is formed, how it repairs and reproduces itself when destroyed. The most minute researches on its structure, merely shew the existence of an infinite number of lamellæ, lying over each other, and overlapping each other, like the tiles of a roof. This *embrication* of the epidermoid lamellæ, is very obvious in fishes and reptiles, the scaly skin of which is merely an epidermis whose parts are much more coarsely shaped.

It was observed (XLII), in the account of absorption, how much friction facilitates the absorption of substances applied to the surface of the skin, by raisng the scales of the epidermis, so as to expose the orifices of the absorbents, whose activity, it in other respects, increases.

Haller conceives, that the epidermis is formed by the drying up of the outer layers of the rete mucosum. Morgagni thinks it is formed by the induration of the skin in consequence of the pressure of the atmosphere. In objection to these hypotheses, one may enquire, how it happens, that by the time the fœtus, immersed in the liquor amnii, has attained its third month, it is covered with such an envelope. Pressure renders the skin hard and callous, increases considerably its thickness, as we see in the soles of the feet and in the palms of the hands of persons engaged in laborious employments. The epidermis reproduces itself with an incredible rapidity, after falling off in scales, after erysipelas or herpetic eruptions, or, when removed, in large flakes, by blistering, it is renewed in the course of a very few days. The cuticle, together with the hairs and the nails, which may be considered as productions of the same substance, are the only parts, in man, that are capable of reproducing themselves. The hairs and the horns of quadrupeds, the feathers of birds, the calcareous matter of the lobster and of several mollusca, the shell of the turtle, the solid sheaths of a number of insects, possess, as well as the epidermis, this singular property. In other respects, the chemical structure of all these parts is the same; they all contain a considerable proportion of phosphate of lime, withstand decomposition, and give out a considerable quantity of ammonia, on being exposed to heat. The use of the epidermis is to cover the nervous papillæ, in which the faculty of the touch essentially resides, to moderate the too vivid impression that would have been produced by an immediate contact, and to prevent the air from drying the skin or from impairing its sensibility.

This desiccation of the cutaneous tissue is further prevented, and its suppleness maintained, by an oily substance, which exudes through its pores, and is apparently secreted by the cutaneous exhalants. This unctuous liniment should not be mistaken for that which is furnished by the sebaceous glands, in certain situations, as around the nostrils, in the hollow of the arm pits, and in the groins. This adipose substance, with which the skin is anointed, is abundant and fetid in some persons, especially in those of a bilious temperament, with red hair. It is, likewise, more copious in the African negroes, as if Nature had been anxious to guard against the too rapid desiccation, by the burning atmosphere of tropical climates. This use of the oil of the skin, is, likewise, answered by the tallow, the fat, and the disgusting substances with which the Caffres and the Hottentots anoint their body, in the manner described under the name of tatooing, by the travellers* who have penetrated into the interior of the burning regions of Africa.

The ancients had a somewhat similar practice, and the anointing with oil, so frequently used in Ancient Rome, answered the same purpose, of softening the skin, of preventing its becoming dry, or chapped†. The pomatums employed at the present day at the toilet, possess the same advantages. The continual transudation of this animal oil renders it necessary, occasionally, to clean the skin by bathing; the water removes the dust and the other impurities which may be attached to its surface by the fluid which lubricates it. It is this humour which soils our linen and obliges us so frequently to renew that in immediate contact with the skin, and which makes the water collect in drops when we come out of the bath, &c.

Though the parts in which there is found the greatest quantity of subcutaneous fat, are not always the most oily, and though one cannot consider this secretion as a mere filtration of this adeps through the tissue of the skin, corpulence has, however, a manifest influence on its quantity. I know several very corpulent persons in whom it appears to be evacuated by perspiration, on their being heated by the slightest exertion. They all grease their linen in less than twenty-four hours. An excess of the oily matter of perspiration is injurious, by preventing the evacuation of the perspiration and its solution in the atmosphere.

We all know how, after the epidermis has been removed, the slightest contact is painful: that of the air is sufficient to bring on a painful inflammation of the skin exposed by the application of a blister. The epidermis, as was likewise mentioned in speaking of the absorption, placed on the limits of the animal economy, and in a manner inorganic, serves to prevent heterogeneous substances from being too readily admitted into the body, and, at the same time, it lessens the too vivid action of external objects on our organs. All organized and living bodies are furnished with this covering, and, in all, in the seed of a plant, in its stem, and on the surface of the body, in man and animals, it bears to the skin the greatest analogy of function and nature. Incorruptibility is, in a manner, its essence, and is its peculiar character; and in tombs which contain merely the dust of the skeleton, it is not uncommon to find whole and in a state to be readily distinguished, the thickened epidermis that forms the sole of the foot and especially the heel. However, this incorruptibility is possessed, as well as others of the qualities of the skin, by the nails and the hairs, which may be considered as its appendages.

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* Among others Kolben, *Description du Cap de Bonne-Espérance* Sparmann, *Voyage au Cap de Bonne Espérance et chez les Hottentots.* Vaillant, *Voyage dans l'Intérieur de l'Afrique.*

† The reply of the old soldier is well known, who, on being aked by Augustus, how he came to live so long, said, he owed his long life to the use of wine inwardly, and to that of oil outwardly; *intùs vino*, extùs oleo.

CXXXII. *Of the nails.* The nails are, in fact, only a part of the epidermis: they are continuous with it, and, after death, fall off along with it. They are thicker and harder; like it they are inorganic and lamellated; they grow rapidly from their root towards their free extremity; they reproduce themselves rapidly and acquire several inches in length, when the part beyond the ends of the fingers and toes has not been removed; as is the case with the Indian fakirs. In this state of developement, they bend over the tips of the fingers and toes, and impair the sense of touch, whose free enjoyment is preferable to any advantages which savages can derive from their long and crooked nails, in defending themselves, or in attacking animals, or tearing to pieces those which they have killed in hunting. The nails are quite insensible, and the reason that so much pain is felt, when the nails run into the flesh, and that the operation of tearing them out, which is sometimes necessary, is so painful, is, that the nerves, over which the nail grows, are more or less injured when it grows in a wrong direction. The pain from the growing of the nails into the quick, is no proof of their being sentient, any more than the growth of corns proves the sensibility of the epidermis, of which they are but thickened parts, become hard and callous by pressure, and which, confined in tight shoes, press painfully on the nerves below. The nail itself may acquire a considerable degree of thickness; I have seen that of the great toe nearly half an inch thick. The use of the nails is to support the tips of the fingers, when they are applied to unyielding substances; they likewise concur in improving the mechanism of the touch*.

CXXXIII. *Of the hair on the head and on other parts of the body.* These parts are treated of, in the present instance, only in consequence of their connexion with the epidermis; as, far from improving the touch, they interfere with it, or at least render it less delicate.

The skin, in man, is more bare than that of other animals; it is, likewise, least covered with insensible parts that might blunt the sense of touch. In almost all mammiferous animals, the whole body is covered with hair, only a small part of the human body has any hair on it, and that in too small a quantity, and of too delicate a texture, to interfere with the touch. Some men, however, have a very hairy skin, and I have seen several who, when naked, looked as if covered over with the skin of an animal, so great was the quantity of hair over the whole body, of which no part was bare, but a small portion of the face, the palms of the hands and the soles of the feet. This extraordinary growth of hair, is, in general, a sure sign of vigour and strength. In childhood, there is no hair except on the head, the rest of the body is covered with down. Women have no beard, and there is in them, a smaller quantity of hair in the arm pits and on the parts of generation, and scarcely any on the limbs and trunk. But as though the matter which should provide for the growth of the hair, were wholly applied to the hairy scalp, it is observed, that their hair is longer and in greater quantity.

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* The toe nails are favourable to the laying the foot to the surface on which the body is supported; they, likewise, improve the sense of touch in this part. The use of the feet is not merely to support the weight of the body, they are, also intended to guide us in feeling for the plane on which we are to rest them, to enable us to judge of the solidity, of the temperature, and of the inequalities of the ground on which we tread. They, therefore, required rather a delicate sense of touch. The division of the fore part of the foot, into several distinct and separate parts, serves to enable us to stand more firmly, and facilitates the action of walking. I have seen several soldiers who lost, from severe cold, the extremities of their feet, in crossing the Alps which separate France from Italy. Those who had lost only their toes, did not walk so steadily, and frequently fell, in treading on uneven ground. Those who had lost one half of their feet, were obliged to use crutches.

The colour of the hair varies from white to jet black; and, as will be mentioned, in speaking of the temperaments and of the varieties of the human species, this difference of colour is a test by which we judge of those varieties. The colour of the hairs enables us to judge of their thickness: Withof, who, with a truly German patience, was at the pains to count how many hairs were contained in the space of a square inch, states, in his dissertation on the human hair, that there are five hundred and seventy two black hairs, six hundred and eight chesnut, and seven hundred and ninety light coloured, so that the diameter of a hair, which is between the three and seven hundredth part of an inch, is least in light hair, and these are finer the lighter their shade. It is, likewise, observed, that men of a bilious constitution, with dark hair, and inhabiting warm climates, have more hair, in other parts of the body, and that it is coarser and more greasy.

In whatever part of the body hairs may grow, they are, every where, of the same structure, they all arise from a vesicular bulb in the adipose cellular tissue; from this bulb containing a gelatinous lymph, on which the hair seems to be nourished, the latter, at first divided into two or three filaments which constitute a kind of root, comes out in a single trunk, passes through the skin and epidermis, receiving from the latter a sheath that covers it to its extremity, which terminates in a point.

A hair may, therefore, be considered as an epidermoid tube filled with a peculiar kind of marrow. This spungy stem, which forms the centre of a hair, is a more essential part of it, than the sheath supplied by the epidermis. Along this spungy and cellular filament, the animal oil of the hair and the juices on which it is repaired flow. Though we see, in some animals, vascular branches and very small nervous filaments directed towards the root of certain kinds of hair, and lost in it, as is the case with the long and stiff whiskers of some of the quadrupeds, it is impossible to say, whether in man, the hair or its bulbs receives vessels and nerves. Is the human hair nourished by the imbibition of the gelatinous fluid contained in its bulb, or is it nourished on the fat in which the latter is imbedded? Are vessels distributed along their axis, from the root to the extremity? In favour of this opinion, it was usual to mention the bleeding from the hair when cut, in the disease called *plica polonica.* But this disease, lately observed in Poland, by the French physicians, appeared to them a mere entangling of hair, in consequence of the filth of the Poles and of their habit of keeping their head constantly covered with a woollen cap. The hairy scalp remains perfectly sound beneath the entangled hair, and the only way to cure the complaint is to cut off the hair. Fourcroy* thinks that each hair has several short branches that stand off from it, which, according to the explanation given by Monge, favour the matting of the hairs that are to be converted into tissues, by the process called felting.

CXXXIV. Among the most remarkable qualities of the hair one may take notice of the manner in which it is affected by damp air, which, by relaxing its substance, encreases its length. It is on that account, that hairs are used for the construction of the best hygrometers. Nor must we omit either the readiness with which they grow and are reproduced, even after being plucked out by the roots, as I have often seen after the cure of tinea by a painful method: nor their insulating property, with respect to the electric fluid, of which they are very bad conductors; a remarkable property, viewed with reference to the conjectured nature of the nervous fluid.

The hairs possess no power of spontaneous motion by which they can rise on the head, when the soul shudders with horror or fear: but they do bristle at those times, by the contraction of the occipito-frontales, which, intimately adhering to the hairy scalp, carries it along in all its motions.

They appear totally without sensibility: nevertheless, the passions have over them such influence, that the heads of young people have turned white the night before execution. The Revolution, which produced, in abundance, the extremes of human suffering, furnished many authentic instances of persons that grew hoary, in the space of a few days. In this premature hoariness, is the hair dried up, as in old people, when it seems to die for want of moisture and its natural juices?

The following fact seems to shew, that they are the excretory organ of some principle, the retention of which might be of very injurious consequence. A chartreux who, every month, had his head shaved, according to the rule of his order, quitting it at its destruction, went into the army, and let his hair grow. After a few months he was attacked with excruciating head aches, which nothing relieved. At last, some one advised him to resume his old habit, and to have his head frequently shaved; the head aches went off, and never returned.

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* *Systême des connoissances chimiques*, tome IX. page 263.

We know, says Grimaud*, that there are nervous head aches, which give way to frequent cropping the hair:—when it is kept close cut, the more active growth that takes place sets in motion stagnating juices. A friend of Valsalva, as Morgagni† relates, dispelled a maniacal affection, by having the head of the patient shaved; Casimir Medicus cured obstinate gonorrhea, by the frequent shaving of the parts of generation.

The hairs partake of the inalterability, the almost indestructibility of the epidermis. Like it, they burn with a fizzing, and give out, in abundance, a fetid ammoniacal oil. The ashes, that remain from burning them, contain much phosphate of lime. The horns of mammiferæ, the feathers of birds, give out the same smell in burning, and yield the same products as the hair on the head and other parts; which has led to the saying that these last were a sort of horny substance drawn out like wire. Acids, but especially alkalies, dissolve them: accordingly, all nations that cut the beard, first soften it, by rubbing it with alkaline and soapy solutions.

Is the use of the hair to evacuate the superabundant nutritious matter? The epoch of puberty and of the termination of growth, is that in which it first springs, in many parts of the body, which were before without it. They are, at the same time, the emunctory by which nature gets rid of the phosphate of lime, which is the residue of the work of nutrition. The hairs of quadrupeds, whose urine abounds less in phosphoric salts than that of man, seem especially to fulfil this destination. The hairs have some analogy with the fat, which has not yet been ascertained. They are often found accidentally developed in the fatty tumours known under the name of steatomas. Finally, they have uses relative to the parts on which they grow.

CXXXV. The faculty of taking cognizance of tangible qualities, belongs to all parts of the cutaneous organ. We have only to apply a substance to any part of the surface of our body, to acquire the idea of its temperature, of its dryness or moisture, of its weight, its consistence and even its particular figure. But no part is better fitted to acquire exact notions, on all these properties, than *the hand*, which has ever been considered as the especial organ of touch. The great number of bones that form its structure, make it susceptible of very various motion, by which it changes its form, adapts itself to the inequalities of the surfaces of bodies, and exactly embraces them: this apt conformation is particularly manifest at the extremities of the fingers. Their anterior part, which is endued with the most delicate feeling, receives, from the median and cubital nerves, branches of some size, which end in rounded extremities, close, and surrounded with a cellular tissue. The part of the fingers, which is called their pulp, is supported by the nails; vessels in great number are spread through this nervo-cellular tissue, and moisten it with abundant juices, that keep up its suppleness. When perspiration is increased, it breaks out, in small drops, over this extremity of the fingers, along the hollow of the concentric lines with which the epidermis is furrowed.

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* *Second Memoir on Nutrition*, p. 49.

† *De Sedibus et Causis*, epist 8, No. 7.

It has been attempted to explain the pleasure we feel in touching rounded and smooth surfaces, by shewing that the reciprocal configuration of the hand and of the body to which it is applied, is such, that they touch in the greatest number of points possible. The delicacy of the touch is kept up by the fineness of the epidermis; it increases by education, which has more power over this sense than over any of the others. It is known with what eagerness a child, allowed the free use of his limbs, stretches his little hands to all the objects within his reach, what pleasure he seems to take in touching them, in all their parts, and running over all their surfaces. Blind men have been known to distinguish, by touch, the different colours, and even their different shades. As the difference of colour depends on the disposition, the arrangement, and number of the little inequalities, which roughen the surface of bodies that appear the most polished, and fit them to reflect such, or such a ray of light, absorbing all the others, one does not refuse to to believe facts of this kind, related by Boyle, and other Natural Philosophers.

Some parts appear endowed with a peculiar touch; such are the lips, whose tissue swells, and spreads out under a voluptuous contact; a vital turgescence, explicable without the supposition of a spungy tissue in their structure:—such are those organs which Buffon considers as the seat of a sixth sense. In most animals, the lips, and especially the lower one, without feathers, scales, or hair, are the organ of a sort of touch, imperfect at best. When the domestic quadrupeds, such as the horse, the dog, the ox, &c. want to judge of the tangible qualities of bodies, you will see them apply to it the end of their nose, the only part where the external covering is without hair: the fleshy appendages of certain birds, and many fish, the antennæ of butterflies, always set near the opening of the mouth, answer the same purpose. The tail of the beaver, the trunk of the elephant, are, in like manner, the parts of their body where touch is most delicate. Observe that the perfection of the organ of touch, ensures to these two animals a degree of intelligence allotted to no other quadruped, and becomes perhaps the principle of their sociability. The books of travellers and naturalists swarm with facts, attesting the wonderful sagacity of the elephant. Some Indian Philosophers have gone the length of allowing him an immortal soul. If birds, notwithstanding the prodigious activity of their life of nutrition, are yet of such confined intelligence, so little susceptible of durable attachment, so restive to education, is not the cause to be assigned in their imperfection of touch? In vain the heart sends towards all their organs, with more force and velocity than in any other animal, a warmer blood, and endued, more remarkably, with all the qualities which characterize arterial blood. In vain is their digestion rapid, their muscular power lively, and capable of long continued motion; certain of their senses, as those of sight and hearing, happily disposed; touch being almost nothing with them, as also the greater number of impressions belonging to this sense, which informs us of the greater part of the properties of bodies; the circle of their ideas must be extremely narrow, and their habits, and manners, much more remote than those of quadrupeds, from the habits and manners of man.

CXXXVI. Of all the senses, the touch is the most generally diffused among animals. All possess it, from man, who, in the perfection of this sense, excels all vertebral animals, to the polypus, who, confined to the sense of touch only, has it, in such delicacy, that he appears, to use a happy expression of M. Duméril, to feel even light. The skin of man is more delicate, fuller of nerves than that of the other mammiferæ: its surface is covered only by the epidermis, insensible indeed, but so thin that it does not intercept sensation, whilst the hairs which cover so thickly the body of quadrupeds, the feathers which clothe that of birds, quite deaden it. The hand of man, that admirable instrument of his intelligence, of which the structure has appeared to some philosophers* to explain sufficiently his superiority over all living species; the hand of man naked, and divided into many moveable parts, capable of changing, every moment, its form, of exactly embracing the surface of bodies, is much fitter for ascertaining their tangible qualities, than the foot of the quadruped, enclosed in a horny substance, or than that of the bird, covered with scales too thick not to blunt all sensation.

CXXXVII. *Of the nerves.* — These whitish cords which arise from the base of the brain, and from the medulla oblongata, are distributed to all parts of the body and give them, at once, the power of moving and feeling. In this analysis of the functions of the nervous system, the most natural order is to consider them merely as conductors of the power of sensation. We shall then see, in what manner, they transmit the principle of motion to the organs by which it is performed. The nerves arise†, from all sentient parts by extremities that are, in general, soft and pulpy, but not alike in all, in consistence and form, and it is to these varieties of arrangement and structure, that the varieties of sensation in the different organs are to be referred.

One may say that there exists, in the organs of sense, a certain relation, between the softness of the nervous extremity, and the nature of the bodies which produce an impression upon it. Thus, the almost fluid state of the retina, bears an evident relation to the subtilty of light. The contact of this fluid could not produce a sufficient impression, unless the sentient part were capable of being set in motion by the slightest impression. The portio mollis of the seventh pair, wholly deprived of its solid covering, and re-

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[*] See the work of Galen, *de usu partium*, cap. 4, 5, 6, and Buffon, *Histoire Naturelle*, tom. IV. et V. 12mo.

[†] In considering the nerves as conductors of sensation, it is correct to say, that they arise from sentient parts, since it is the extremity most distant from the brain, which experiences the *sensitive impression*, that is propagated to the organ itself, along the course of the nerve. In attending, on the contrary, to the phenomena of motion, the nerves are considered to arise from the brain, for, it is from the centre to the circumference, that the principle of motion is transmitted to the muscles called, by Cullen, *moving extremities of the nerves*. Some anatomists have considered it as a doubtful point, whether the nerves arise from the brain and spinal marrow, or whether these parts are formed by the union of the nerves.

duced to its medullary pulp, readily partakes in the sonorous motions transmitted to it by the fluid, in the midst of which its filaments are immersed. The nerves of smell and of taste are more exposed, than the nervous papillæ of the skin employed in receiving the impressions produced by the coarser properties of bodies, &c.

From their origin, the nerves ascend towards the medulla oblongata and the spinal marrow, in a line nearly straight, and seldom tortuous, as most of the vessels. When they have reached these parts, they terminate in them, and are lost, in their substance, as will be mentioned, in speaking of the structure of these nervous cords.

CXXXVIII. Every nerve is formed of a great number of filaments, extremely delicate, and which have two extremities, the one in the brain and the other from the part into which they terminate, or from which they originate. Each of these nervous fibres, however minute, is composed of a membranous tube which is a production of the pia mater. Within the parietes of this tube, there are distributed innumerable vessels of extreme minuteness; it is filled within, with a whitish marrow, a kind of pulp, which Reil states he insulated from the small canal containing it, by concreting it, by means of the nitric acid, which dissolves the membranous sheath, and leaves uncovered the medullary pulp forming the essential part or basis of the nervous filament. This same physiologist discovered, by a different process, the internal structure of each nervous fibrilla; he dissolved the whitish or pulpy part, by a long continued solution in an alkaline ley, and he succeeded thus in separating it from the membranous tube which inclosed it and which was emptied. The membranous sheath is of cellular structure and is remarkable only by its consistence and by the very considerable number of vessels of all kinds that are distributed to its parietes; it ceases to cover the nerves, near their two extremities and protects them, only along their course.

Each nervous fibre, thus formed of two very distinct parts, joins other fibres of a perfectly similar structure, to form a nervous filament enveloped in a common sheath of cellular tissue. These filaments, by their union, form small ramifications, and these progressively larger branches, and lastly, trunks wrapped in a common covering of cellular tissue; then other envelopes to each fasciculus of filaments, and lastly, a sheath to each individual filament.

When nervous cords are of a certain size, veins and arteries of a pretty considerable caliber, may be seen to insinuate themselves between the bundles of fibres of which they are composed; these vessels then divide, after penetrating among them, and furnish the capillary ramifications which are distributed to the parietes of the sheath common to each filament. These small vessels, according to Reil, allow the nervous substance to exhale into each membranous tube; this, likewise, becomes the secretory organ of the medulla with which it is filled.

CXXXIX. The nervous filaments unite, or are separated from one another, but do not run into each other. The divisions of the nerves are different from those of the arteries, and their mode of junction does not admit of being compared to that of the veins. It is, in the first instance, a mere separation; in the second, an approximation of filaments which had been separated, and which, though united in common sheaths, have, nevertheless, each a proper covering, are merely in juxta position and perfectly distinct. If that were not the case, one could not say, that each fibre has one extremity in the brain, and the other in some one point of the body, nor could one conceive how the impressions which several sentient extremities receive at once, reach the brain without running into each other; nor, in what manner, the principle of motion could be directed towards a single muscle receiving its nerves from the same trunk as the other muscles of the limb.

In general, the nerves divide from each other and unite at an angle more or less acute, and equally favourable to the circulation of a fluid, from the circumference to the centre, and from the centre to the circumference.

The structure of the nerves is different according to their situation. Thus, the medullary fibres of the optic nerve, are not furnished with membranous coverings, the pia mater alone furnishing a sheath to the cord formed by the union of these filaments; the dura mater adds a second coat to it, on its leaving the skull. This coat, belonging, likewise, to the whole nerve, is not continued over it, after it has entered the eye ball, and is lost in the sclerotica. A minute artery passes through the centre of the optic nerve and then dividing, forms a rete mirabile which supports the medullary pulp of the retina. The nerves which pass along osseous canals, as the Vidian nerve of the fifth pair, are not provided with a cellular covering, and their consistence is always greater than that of the nerves which are surrounded by soft parts.

CXL. On reaching the brain, the medulla oblongata, or the spinal marrow, every nervous filament, as was already mentioned, parts with its membranous covering, which is lost in the pia mater, or immediate covering of these central parts of the brain. The medullary or white part of the brain is continued into their substance, which may be considered as principally formed by the assemblage of these nervous extremities which it is difficult to distinguish in its tissue, from its want of consistence. It has long been known, that the origin of the nerves is not the spot at which they are detached from the brain, that they sink into the substance of this viscus, in which their fibres cross each other, so that those on the right pass to the left, and vice versâ. Sœmmering thought, that the roots of the nerves, especially of the nerves of the organs of sense, reached to the prominences in the parietes of the ventricles of the brain, and that their furthest extremity was moistened by the serosity which keeps these inward surfaces in contact. It has likewise, long been thought, that the cerebral extremities of the nerves all joined in a fixed point of the brain, and that to this central point, all sensations were carried, and that from it, all the determinations producing voluntary motion arose. But the inquiries of Gall on the structure of the brain and nervous system, have completely overset these various hypothesis.

The spinal marrow and the nerves, in the different animals furnished with them, are larger in proportion to the brain, according as the animal is more distant from man in the scale of animation. In carnivorous animals, the prodigious developement of the muscles required nerves of motion of a proportionate size; hence, in them, the cerebral mass, compared to the nerves and spinal marrow, is very inconsiderable. It is observed, that there exists the same relation, in men of an athletic disposition; the whole nervous power seems employed in moving their large muscles, and the nerves, though very small, in proportion to the rest of the body, are, however, very large, if compared to the cerebral organ. In children, in women, and in individuals possessed of much sensibility, the nerves are very large, in proportion to the other parts of the body, they decrease in size and shrink, in persons advanced in years; the cellular tissue which surrounds them, becomes more consistent, adheres to them more closely, and there exists a certain analogy between the nerves of old men, enveloped by that yellowish tissue, which makes their dissection laborious, and the branches of an old tree covered over by a destructive moss.

As the uses of the nerves cannot be explained independantly of those of the brain, I shall now go on to consider this important viscus.

CXLI. *Of the coverings of the brain.* If it be true, that one may judge of the importance of an organ, by the care which Nature has taken to protect it from external injury, no organ will appear of greater importance than the brain, for, no one appears to have been protected with greater care. The substance of this viscus has so little consistence, that the slightest injury would have altered its structure, and deranged its action; hence it is powerfully guarded by several envelopes, the most solid of which, is the bony case, in which it is contained.

No part of anatomy is better understood, than that of the many bones which, by their union, form the different parts of the human head. Every thing that relates to the place they occupy, to their respective size, to their projections and depressions, to the cavities whose parietes they form, every thing that relates to their internal structure, to the different proportions of their component parts, to the aggregation of some of these substances, in certain points of their extent, has been described by several modern anatomists, with an accuracy which it would not be easy to surpass. Several, however, have not sufficiently appreciated the direct influence of their mode of action on the functions which they are destined to fulfil; no one has insisted sufficiently on the manner in which they all concur to a principal object; the preservation of the organs enclosed within the skull.

Hunauld, in a memoir inserted among those of the Academy of Sciences, for the year 1730, was the first that endeavoured to account for the arrangement of the articulating surfaces of the bones of the skull. After laying down a few principles on the theory of arches, and after shewing, that the difference of extent of their concave and convex surfaces, rendered it necessary that the parts of which they are formed, should be shaped obliquely, he explains the advantages of the squamous articulation between the temporal and parietal bones.

When the arch of the cranium is loaded with a very heavy burthen, the temporal bones prevent the parietals on which the effort is immediately applied, from being forced inwardly, or from being separated outwardly. Hunauld very aptly compares them to buttresses which are to the parietal bones of the same use as walls to the arches which they support.

Bordeu* endeavoured to apply to the bones of the face, the principles by which Hunauld had been guided in his investigation with regard to those of the skull. According to Bordeu, the greater part of the bones of the upper jaw, but particularly the superior maxillary bones, resist the effort of the lower jaw, which, by acting on the upper dental arch, has a perpetual tendency to force upward, or to separate outwardly, the bones in which the teeth of that jaw are inserted. As the greatest stress of the effort determines them upward, it is, likewise, in that direction, that the bones of the upper jaw rest most powerfully on those of the skull. The author concludes this very ingenious memoir, by proposing to physiologists, the solution of the following problem, "When a "man supports a great weight on his head, and holds at the same "time any thing very firmly between his teeth, which is the bone "of the head that is most acted upon; which supports the weight "of the whole machine?"

The body of the sphenoid, and especially its posterior half, appears to me to be the central point on which the united efforts of the bones of the skull and of the face act, in the case supposed by Bordeu.

The sphenoid is connected with all the other bones of the skull; it is immediately connected with several of the bones of the face, as with the malar bones, with the palatine bones, with the vomer, and, sometimes, with the superior maxillary bones. These bones of the face, in the case in question, alone support the lower jaw against the upper. The ethmoid bone, the ossa unguis, and the inferior turbinated bones are thin and frail, and serve merely to form the nasal fossæ, of which they increase the windings, and do not deserve to be attended to in this investigation. The vomer may, it is true, communicate to the ethmoid, in an inferior degree, a part of the effort; for, the anterior part of its upper edge is articulated with the perpendicular lamella of that bone; but this quantity is very small, as the vomer is thin and transmits it, almost wholly, to the body of the sphenoid, with the lower face of which it is articulated.

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* *Académie des Sciences, Mémoires présentés par les savans étrangers.* Tome III.

The effort exerted on the bones of the upper jaw, is transmitted, by means of the nasal processes of the upper maxillary bones, by the orbitar and zygomatic processes of the malar bones, and by the upper edge of the palate bones and of the vomer, to the frontal, to the temporal, and sphenoidal bones.

If we wish to determine what becomes of the greater part of the effort transmitted to the frontal bone by the maxillary and malar bones, we may observe, in the first place, that it is articulated with the sphenoid bone, by the whole of its lower edge which is bevelled at its inner part, so that it is covered by the alæ minores of the os sphenoides, which is shaped obliquely at the outer part of the bone. The frontal bone is articulated, besides, with the lateral and inferior parts of its upper edge. The remainder of this upper part is united to the anterior edge of the parietal bones, which, by means of a slope, in a different direction, rest on the middle part of this edge, while the frontal bone is applied to them laterally.

This bone, which the effort tends to force upward and backward, cannot yield to this double impulse, for, on the one hand, its mode of articulation with the anterior edge of the alæ minores of the sphenoidal bone, and the internal part of the anterior edge of the parietal bones, resist this tendency upward, while the resistance from the latter, prevents them from being forced backward. That share of the effort which affects the parietal bones, follows the curved line described by these bones, and extends along that formed by the occipital, and thus reaches the posterior face of the body of the sphenoid bone.

The portion directly transmitted to the anterior and inferior face of this bone, by the ossa palati and by the vomer, is inconsiderable, and proportioned to their thinness. The anterior half of the body of the sphenoid bone, hollowed by the sphenoidal sinus, would have been incapable of supporting greater pressure. Lastly, the situation of the body, placed between the dental arches, in front of the place occupied by the ossa palati, explains, why this transmission is chiefly effected by the upper maxillary bones.

The above is the manner in which the effort exerted from below upward, by the lower on the upper jaw, is carried to the anterior, posterior, and inferior faces of the body of the sphenoid bone.

The temporal bones which are affected by it, in a very slight degree, by means of the zygomatic processes of the malar bones, support the greater weight of the effort acting from above downward, or from the arch of the skull towards its base. The weight laid on the head, tends to depress or to separate the parietal bones, which resist the pressure, in consequence of the support afforded them by the temporals. These transmit the effort to the lateral and posterior parts of the body of the sphenoid, by means of the alæ majores of that bone, which are articulated, along the whole extent of their external edge, and along the posterior fourth of their internal edge, with the temporals. Besides, the upper extremity of the alæ majores is sloped, on the inner part of the bone, that it may be articulated with the anterior and inferior angles of the parietal bones, and answer the same purpose to them as the squamous portion of the temporals.

The lateral and posterior parts of the body of the sphenoid support, therefore, almost the whole effort of the pressure applied to the parietal bones. Is is communicated to them by the alæ majores, which receive it themselves, either directly at the anterior and inferior angles of this bone, or through the medium of the temporals. The small portion of the effort transmitted by the latter to the occipital, follows the curved line of this bone and is felt on the posterior face of the body of the sphenoid.

To the effort resulting from the pressure exerted by the body on the summit of the head, one should add that occasioned by the contraction of the muscles which elevate the lower jaw. These tend to depress the temporal, the malar and sphenoid bones, and in this action, they employ a power equal to that by which they raise the lower jaw, and press it firmly against the upper.

The effort exerted from the arch to the base of the skull depends, therefore, on two very different causes; the portion resulting from the action of the elevators of the lower jaw, is equal to the effort exerted from below upward, by this bone. After what has been stated, it would be useless to say any thing further of the manner in which the effort is transmitted: we may merely observe, that the least powerful of these muscles, the internal pterygoid, tends to draw the sphenoid downward, and prevents this bone, fixed like a wedge with its base turned upward, from being disengaged by the effort applied to it, by the bones between which it is situated.

The posterior, anterior, inferior and lateral faces of the sphenoid bone, support, therefore, the whole effort of the bones of the skull and face, on one another, when the top of the head being loaded with a heavy burthen, one presses, at the same time, something very firmly between the dental arches.

The anterior part of the body of the bone, containing the sphenoidal sinus, is thin and very frail; the posterior part, corresponding to the sella turcica, is alone capable of resisting the effort which, I believe, it is destined to sustain*; hence, it is at this point, that ossification begins, and this confirms the observation of Kerkringius, that the spot at which bones begin to ossyfy, is that on which they have to bear the greatest effort; hence the alæ majores, by means of which the greatest part of the efforts which the body of the sphenoid has to support, arise from the lateral parts of its posterior half, by an origin of considerable size, and which is further increased by the base of the pterygoid processes which arise from its lower part.

I have, in this enquiry, purposely avoided mentioning the support which the head receives from the vertebral column and which, in the case under consideration, is of use merely in preventing it from yielding to the law of gravitation. If the bones of the skull and of the face had pressed, during the effort which they sustain, on the circumference of the foramen magnum; this aperture would have been incapable of increasing its dimensions, and this would have been attended with the most serious inconveniences.

The name given by the ancients to the bone whose principal use has just been explained, is composed of sphenos, which means a wedge, and eidos, which signifies resemblance, and would lead one to think, that they were not ignorant of its uses. From its situation, at the middle and inferior part of the skull, and from its various connexions with the bones which form this osseous case, it is to them of the same use as the key stone of arches, with regard to the different parts of which they are formed. The numerous connexions required for this purpose, account for its strange and irregular form and for the different shapes of its articular surfaces and the great number of its projections, which render the demonstration of this bone so complicated, and a knowledge of it so difficult.

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* The sphenoidal sinus is prolonged, it is true, into this posterior part of the body of the bone, in persons considerably advanced in years; but the parietes of this portion of its cavity are of considerable thickness. The anterior part of the basilary process of the occipital bone, is then firmly united to the sphenoid and may be considered as forming a part of that bone, from which it cannot be detached. The cranium of an old man, in this respect, resembles that of several quadrupeds, in which the union of the sphenoid to the occipital bone takes place so early, that these two bones might well be considered as forming but one.

It is more advantageous, with regard to the brain, that the skull should be formed of several bones, than if it had consisted of a single bone. It resists, more effectually, the blows it receives, their effect being lessened, in passing from one bone to the other, and being interrupted, in the obscure motions which they may experience at their sutures; its rounded form increases, likewise, its power of resistance. This force would be equal, in every point of the parietes of the cranium, if the form of that cavity were completely spherical, and if the thickness of its parietes were, in every part of it, the same. In that case, no fractures by *contre coup* could occur, a kind of lesion occasioned by the unequal resistance of the bones of the head, to the force applied to their surface. The pericranium, the hairy scalp, the muscles which cover it, and the great quantity of hair on its surface, serve, besides, to defend the brain, and are well calculated to break the force of blows applied to the cranium.

In addition to this hard and unyielding case, there lies over the brain, a treble membranous covering, formed by the dura mater, which owes its name to the erroneous opinion according to which it was supposed to form all the other membranes of the body; it is further covered by the tunica arachnoidea, so called from the extreme minuteness of its tissue, and by the pia mater which adheres firmly to the substance of the brain.

The dura mater lines, not only the inside of the skull and of the vertebral canal, which may be considered as a prolongation of it, but, likewise, penetrates between the different parts of the cerebral mass, supports them in the different positions of the head, and prevents mutual compression. Thus, the greatest of its folds, the falx, stretched between the crysta galli of the ethmoid bone, and the inner protuberance of the occipital bone, prevents the two hemispheres of the brain, between which it lies, from compressing each other, when the body is on the side, and maintains, on the other hand, the tentorium cerebelli in the state of tension necessary to enable it to support the weight of the posterior lobes of the brain. This fold of dura mater is of a semi-circular form, separates the portion of the skull which contains the brain, from that in which the cerebellum is situated. It is kept in a state of tension by the falx cerebri, on which it also exerts the same action: it does not present an horizontal plane to the portion of brain which lies upon it, but one that slopes, in every direction, towards the parietes of the skull, to which it transmits most of the weight which it has to support. The tentorium cerebelli, which thus divides the internal cavity of the skull into two parts of unequal dimensions, is bony in some animals that move by bounding and with rapid action; this is the case with the cat, which can, without being stunned, take leaps from a considerable height. By means of this complete partition, the two portions of the brain are prevented from pressing on each other, in the violent concussions which they experience.

The tunica arachnoides, according to Bonn*, who was thoroughly acquainted with its structure and who has given a very beautiful plate of it, is the secretory organ of the serum which moistens the internal surface of the dura mater, a fibrous membrane which serves as a periosteum to the bones it lines.

CXLII. *Of the size of the brain.* Of all animals, man has the most capacious skull, in proportion to his face, and, as the bulk of the brain is always of a size proportioned to that of the osseous case which contains it, the brain is also most bulky in man. This difference of size between the cranium and face, may be taken as the measure of the human understanding and of the instinct of the lower animals; the stupidity and ferocity of the latter are greater, according as the proportions of these two parts of their skull, vary from those of the human head.

To express this difference of size, Camper imagined a vertical line, drawn from the forehead to the chin, and perpendicular to another drawn in the direction of the base of the skull. He has called the first of these lines *facial*, the second, *palatine* or *mental.* It is easy to understand, that, as the projection of the forehead is determined by the size of the skull, the larger it is, the more the angle at which the facial line meets that from the base of the skull must be obtuse. In a well formed European head, the facial line meets the palatine at an angle nearly straight (of between 80 and 90 degrees). When the angle is quite straight, and the line which measures the height of the face is completely vertical, the head is of the most beautiful form possible, it approaches most to that conventional degree of perfection which is termed ideal beauty. If the facial line slopes backward, it forms with the palatine line, an angle more or less acute, and projecting forward, the inclination increases, and the sinus of the angle is shorter; if, from man, we pass to monkeys, then to quadrupeds, to birds, reptiles, and fishes, we find this line slope more and more, and, at last, become almost parallel to the mental, as in reptiles and in fishes, with flat heads. If, on the contrary, we ascend from man to the Gods, whose images have been transmitted to us by the ancients, we find the facial line to incline in a different direction, the angle then enlarges and becomes more or less obtuse. From this inclination forward of the facial line, there results an air of grandeur and majesty, a projecting forehead, indicating a voluminous brain and a divine intellect.

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* *Dissertatio de continuationibus membranarum.* 4° Lugdun. Bat. 1763.

To obtain, with precision, by this means, the respective dimensions of the skull and face, one must measure, not only the outside, but, likewise, draw the tangents on the internal surfaces, after dividing the head vertically. There are, in fact, animals, in which the sinuses of the frontal bone are so large, that a considerable portion of the parietes of the skull is protruded by their cells. Thus, in the dog, in the elephant, in the owl, &c. the apparent size of the skull exceeds much its real capacity.

The relative size of the head, and consequently the proportionate bulk of the brain is inconsiderable, in very tall and muscular subjects; this fact will be confirmed by observing the proportions of antique statues. In all those which represent heroes or athlets gifted with a prodigious bodily power, the head is very small, in proportion to the rest of the body. In the statues of Hercules, the head scarcely equals in size the top of the shoulder. The statues alone of the King of the Gods, present the singular combination of an enormous head, resting on limbs of a proportionate size, but the Greek artists have transgressed the laws of Nature, only in favour of the God that rules over her, as if a vast brain had been necessary to one whose intellect carries him, at a glance, over the whole universe. The relative small dimensions of the head, in athlets, depend on this circumstance, that in such men, the excessive developement of the organs of motion, gives to the body, and especially to the limbs, an enormous size, while the head covered by few muscles, remains very small. Sœmmering has stated, that the head in women is larger than in men, and that their brain is heavier; but it must be recollected, that this great anatomist obtained this result, by examining two bodies, male, and female, of the same length. Now, the absolute size being the same, the proportionate magnitude was not so, and he was wrong in comparing the head, the skull, and brain of a very tall woman, to that of a very short man.

It has long been thought, that there exists a connexion between the bulk of the cerebral mass and the energy of the intellectual faculties. It has been thought, that, in general, men whose mind is most capacious, whose genius is most capable of bold conceptions, had a large head supported on a short neck. The exceptions to this general rule have been so numerous, that many have doubted its truth; should it then be absolutely rejected, and will it be allowed to be wholly without foundation, when we consider that man, the only rational being out of so great a number, and some of which bear to him a considerable resemblance both of organization and structure, is, likewise, the only animal in which the brain, properly so called, is largest in proportion to the cerebellum, to the spinal marrow, to the nerves and to the other parts of the body? Why may it not be with the brain, as with the other organs, which fulfil their functions the better, from being more completely developed? It should be recollected, in this comparison of the brain and of the intellectual powers, that several causes may give to this viscus an unnatural degree of enlargement. Thus, in subjects of a leucophlegmatic temperament, the tardy ossification of the bones of the skull, causes the brain, gorged with aqueous fluids, to acquire a considerable size, without its containing a greater quantity of real medullary substance. Hence it is observed, that men of this temperament are, most frequently, unfit for mental exertion, and rarely succeed in undertakings that require activity and perseverance*.

CXLIII. *Structure of the cerebral mass.* What we know of the brain, serves only to shew us that we are ignorant of much more. All that we know of it consists of notions tolerably exact of its external conformation, its colour, its density, and of the different substances that enter into its composition; but the knowledge of its intimate structure is yet a mystery, which will not be so soon unveiled to us. The brain, properly called, is divided by a longitudinal furrow, into two lobes of equal bulk. Gunzius, however, imagined that he found the right lobe, or hemisphere, a little larger than the left; but even were this fact as certain as it is doubtful, we could not thereby explain the predominant force of the right side of the body, since the nerves which are distributed to this side, rise from the left lobe of the brain, in the substance of which all the roots of these cords cross. This fact of the crossing of the nerves, at their origin, is proved by a multitude of pathological observations, in which the injury of a lobe is always found to bring on paralysis, convulsion, or any other symptomatic affection, on the opposite side of the body. Unless you chuse to explain this phenomenon by admitting a necessary equilibrium in the action of the two lobes; an equilibrium, the disturbance of which is the occasion that the sound lobe, acting with more force, compresses the origin of the nerves on its side, and determines paralysis. Might the want of judgment, the unevenness of humour and character, depend on the want of harmony between the two corresponding halves of the cerebral mass?

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* See, in the article on Temperaments, an account of the influence of the physical organization on the moral disposition and on the intellectual faculties.

In order to disclose, better than had before been done, the structure of the brain, M. Gall begins his dissection at the lower part, examining, in the first place, the anterior part of the prolongation, known under the name of cauda of the medulla oblongata, he finds the two pyramidal eminences. If you part the two edges of the median line, below the furrow which separates the two pyramids, you see distinctly the crossing of three or four cords or fasciculi of nerves, which, consisting of many filaments, tend obliquely from right to left, and *vice versâ*. This crossing of nervous fibres, which is not found in any other part of the brain, had been observed by several anatomists. It is not known how it came to be forgotten, so that the most exact and the latest among them, Boyer, for instance, say that the crossing of the nerves cannot be proved by anatomy. These nervous cords, traced upwards, enlarge, strengthen, and forming pyramidal eminences, ascend towards the tuber annulare. Having reached this ganglion, the fibres strike into it, and are lost in a mass of pulpy or greyish substance, of the same nature as that, which, under the name of cortical substance, covers the two lobes of the brain. This greyish pulp, distributed in various parts, may be considered, agreeably to the views of M. Gall, who calls it the matrix of the nerves, as the source from which the medullary fibres take their origin. These ascending fibres cross other transverse fibres, which, on either side, proceed from the crura of the cerebellum; enlarged and multiplied by means of their passage through the grey substance which is found in the tuber annulare; they rise from it, at its upper part, in two fasciculi which compose nearly the whole of the crura cerebri. The interior of these crura, contains a certain quantity of grey substance, which is what nourishes the nervous fibre. On reaching the ventricles, these peduncles, or rather the two fasciculi of fibres which form them, meet with large ganglions full of grey substance; they have long been called thalami optici, though they do not give origin to the optic nerves. There the fibres are sensibly enlarged; and they pass from the thalami optici into new ganglions. These are the corpora striata, and the striæ which are apparent on cutting these pyriform masses of grey substance, are only the same fibres, which, enlarged, multiplied, and radiating, spread out in the manner of a fan, towards the lobes of the brain, where, after forming by their expansion a whitish and fibrous substance, they terminate at the outer part of that viscus, forming its convolutions all covered with the substance in which are terminated, in like manner, the extremities of the diverging fibres. From this grey substance, proceed converging fibres, tending from all parts of the periphery to the centre of the brain, where they unite to form the different commissures, the corpus callosum, and other productions, destined to facilitate the communication of the two hemispheres.

The exterior of the brain may, therefore, be considered as a vast nervous membrane, formed by the grey substance. To form a due conception of its extent, it must be understood, that the convolutions of the brain, are a sort of duplicatures, susceptible of extension by the unfolding of two contiguous medullary laminæ, which form its base. The exterior surface of the brain, by means of this unfolding, offers then some relation to the skin, a vast nervous expanse every where covered by a sort of pulpy substance, known by the name of the rete mucosum of Malpighi. M. Gall compares this cutaneous pulp, to the cineritious substance which forms the outer part of the brain, and, I must confess, it is not every one that will admit the analogy. However, true it is, that the brain consists, principally, of a mass of ganglions, that it produces neither the elongated medulla, nor the spinal marrow, that this last may be considered as a series of ganglions, united together, that the vertebral nerves arise from the greyish pulp of which the spinal marrow is full, as is best seen in animals without a brain, but not the less provided with a spinal marrow, or series of ganglions, from which the nerves arise. The ganglions, or rather the grey substance which they always shew, produce the nervous fibres, and thicken the nervous cords that pass through them.

That is the only use that can be assigned to these parts of the nervous system; for, if they were meant to withdraw from the dominion of the will, the parts in which they are found, why do not the ganglions of the vertebral nerves fulfil the same function? All these nerves communicate by reciprocal anastomoses. These communications, in man, are equivalent to a real continuity. In truth, the brain acts upon the nerves that proceed from the spinal marrow, as if this were one of its productions, and all the nervous fibres, spread through the different organs, had an extremity terminating in this viscus.

One thing well worthy of attention, and on which no anatomist has dwelt, is that the brain of the fœtus, and of the child just born, appears to consist, almost entirely, of a cineritious pulp, to such a degree that the medullary substance is difficult to perceive in it. Would it be absurd to believe, that the medullary part of the brain does not take its perfect organization till after birth, by the developement of the fasciculi of medullary fibres, in the midst of these masses of cineritious substance, which must be considered as the common source from which the nerves have their origin, or, to use the language of Gall, as the uterus which gives them birth. The almost total inactivity, the passive state of the brain in the fœtus, makes unnecessary there the existence of the medullary apparatus, to which the most important operations of intelligence seem entrusted. Its first rudiments are found in the fœtus at its full time. That fibro-medullary apparatus will be strengthened by the exercise of thought, as the muscles are seen to enlarge and perfect their growth, by the effect of muscular action.

CXLIV. *Circulation of the brain.* I have said that the blood, in its circular course, does not traverse the different parts of the body with uniform velocity: that there are partial circulations in the midst of the general circulation. In no organ are the laws, to which this function is subjected, more remarkably modified than in the brain. There is none which receives, in proportion to its bulk, larger arteries and more in number. The internal carotid and vertebral arteries, as we may satisfy ourselves from the calculations of Haller, carry thither a great portion of the whole quantity of blood that flows along the aorta; (from a third to the half).

The blood which goes to the brain, said Boerhaave, is more aërated than that which is distributed to the other parts: the observation is not without foundation. Though the blood which the contractions of the left ventricle send into the vessels, arising from the arch of the aorta, does not undergo, at the place of this curvature, a mechanical separation carrying its lighter parts towards the head; it is not less true, that this blood, just passing from the contact of the air in the lungs, possesses, in the highest degree, all the peculiar qualities of arterial blood. So great a quantity of light, red, frothy blood, impregnated with caloric and oxygen, coming upon the brain, with all the force it has received from the action of the heart, would unavoidably have deranged its soft and delicate structure, if nature had not multiplied precautions to weaken its impulse.

The fluid, compelled to ascend against its own weight, loses, from that alone, a part of its motion. The vertical column must strike against the angular curvature which the internal carotid takes in its passage along the osseous canal of the petrous portion of the temporal bone, and as this curvature, supported by hard parts, cannot straighten itself, the column of blood is violently broken and turned out of its first direction, with considerable loss of velocity.

The artery immersed in the blood of the cavernous sinus, as it comes out from the carotid canal, is very easily dilated. Finally, the branches into which it parts, on reaching the base of the brain, have coats exceedingly thin, and so weak that they collapse, when they are empty, like those of the veins. This weakness of the cerebral arteries, explains their frequent ruptures, when the heart sends the blood into them too violently; and it is thus, that the most part of sanguineous apoplexies are occasioned, many of which, however, take effect without rupture, and by the mere transudation of blood through the coats of the arteries. These vessels, like the branches arising from their divisions, are lodged in the depressions with which the base of the brain is furrowed, and do not enter its substance, till they are reduced to a state of extreme tenuity, by the further divisions they undergo, in the tissue of the pia mater.

Notwithstanding the proximity of the brain to the heart, the blood reaches it, then, with an exceedingly slackened motion: it returns, on the contrary, with a motion progressively accelerated. The position of the veins at the upper part of the brain, between its convex surface and the hollow of the skull, causes these vessels, gently compressed by the alternate motions of rising and falling of the cerebral mass, to disgorge their contents readily into the membranous reservoirs of the dura mater, known by the name of sinuses. These, all communicating together, offer to this fluid a sufficiently large receptacle, from which it passes into the great jugular vein, which is to carry it again into the general course of the circulation. Not only is the caliber of this vein considerable, but its coats too, of little thickness, are very extensible; so much so that it acquires, by injection, a caliber superior to that of the venæ cavæ. The flowing of the blood is favoured by its own weight, which makes a retrogade course very difficult*.—Thus, to sum up all that is peculiar in the cerebral circulation, the brain receives, in great quantity, a blood abounding in oxygen; the fluid finds, in its course thither, many obstacles which impede and slacken its impulse, whilst all, on the contrary, favours its return and prevents venous congestion.† Let me observe, to conclude what I have to say on the circulation of the brain, that of the eye is nearly allied to it, since the opthalmic artery is given out by the internal carotid, and the opthalmic vein empties itself into the cavernous sinus of the dura mater. Accordingly, the redness of the conjunctiva, the prominence, the brightness, the moistness of the eyes, indicate a stronger determination of the blood towards the brain. Thus the eyes are animated at the approach of apoplexy, in the transport of a burning fever, during delirium, a dangerous symptom of malignant or ataxic fevers. On this connexion of the vessels of the eye and brain, depends the lividity of the conjunctiva, whose veins, injected with a dark coloured blood, indicate the fulness of the brain in the generality of cases of suffocation.

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* In preventing this reflux, there is no use of valves, which the jugular vein is entirely without. It is sufficiently prevented, by the direction in which the blood flows, and the extensibility of its coats. This great size which the vein can acquire, would have made useless the valvular folds, insufficient to stop the canal, in that great augmentation of its dimensions.

† The transverse anastomoses of the arteries, at the base of the brain, are very proper for distributing the blood, in equal quantity, to all parts of this viscus.

CXLV. *Of the connexion between the action of the brain and that of the heart.* It is possible, as was done by Galen, to tie both carotids, in a living animal, without his appearing sensibly affected by it; but if, as has never yet been done, both the vertebral arteries are tied, the animal drops instantly and dies, at the end of a few seconds. To perform this experiment, it is necessary, after tying the carotid arteries of a dog, to remove the soft parts which cover the side of the neck, then with needles, bent in a semi-circular form, passed into the flesh along the sides of the articulation of the cervical vertebræ, to apply ligatures to the arteries which ascend along their transverse processes. The same effect, viz. the speedy death of the animal is produced by tying the ascending aorta in an herbivorous quadruped.

These experiments, which have been repeated a number of times, decidedly prove the necessity of the action of the heart on the brain, in preserving life. But how does this action operate? Is it merely mechanical? Does it consist solely in the gentle pressure which the arteries of the brain exert on the substance of this viscus, or is it merely, to the intercepted arterial blood which the contractions of the heart determine towards the brain, that death is to be attributed? The latter opinion seems to me the most probable, for, if, the moment the vertebrals have been tied, the carotids are laid open, and the pipe of a syringe adapted to them, and any fluid whatever is then injected with a moderate degree of force, and at nearly the same intervals as those of the circulation, the animal will not be restored to life.

The heart and brain are, therefore, united to each other by the strictest connexion, the continual access of the blood flowing along the arteries of the head is, therefore, absolutely necessary to the preservation of life; if intercepted, for one moment, the animal is infallibly destroyed.

The energy of the brain appears, in general, to bear a relation to the quantity of arterial blood which it receives. I know a literary man, who, in the ardour of composition, exhibits all the symptoms of a kind of brain fever. His face becomes red and animated, his eyes sparkling; the carotids pulsate violently; the jugular veins are swollen, every thing indicates that the blood is carried to the brain with an impetus, and in a quantity proportioned to its degree of excitement. It is, indeed, only during this kind of erection of the cerebral organ, that his ideas flow without effort, and that his fruitful imagination traces, at pleasure, the most beautiful descriptions. Nothing is so favourable to this condition as remaining long in a recumbent posture; in this horizontal posture, the determination of the fluids towards the head is the more easy, as the limbs, which are perfectly quiescent, do not divert its course. He can bring on this state by fixing his attention steadfastly on one object. May not the brain, which is the seat of this intellectual action, be considered as a centre of fluxion; and may not the stimulus of the mind be compared, as to its effects, to any other stimulus, chemical or mechanical?

A young man of a sanguineous temperament, subject to inflammatory fevers which always terminate by a profuse bleeding at the nose, experiences, during the febrile paroxysms, a remarkable increase of his intellectual powers and of the activity of his imagination. Authors had already observed, that in certain febrile affections, patients of very ordinary powers of mind, would sometimes rise to ideas which, in a state of health, would have exceeded the limits of their conception. May we not adduce these facts in opposition to the theory of a celebrated physician, who considers a diminution of the energy of the brain to be the essential character of fever?

It is well known that the difference of the length of the neck, and, consequently, the greater or lesser degree of vicinity of the heart and brain, give a tolerably just measure of the intellect of man, and of the instinct of the lower animals; the disproportionate length of the neck has ever been considered as the emblem of stupidity.

In the actual state of our knowledge, is it possible to determine in what manner arterial blood acts on the brain? Are oxygen or caloric, of which it is the vehicle, separated from it by this viscus, so as to become the principle of sensation and emotion, or do they merely preserve it in the degree of consistence necessary to the exercise of its functions? What is to be thought of the opinion of those chemists who consider the brain, as a mere albuminous mass, concreted by oxygen, and of a consistence varying in different persons, according to the age, the sex, or the state of health or disease? Any answer that one might give to these premature questions, would be but a simple conjecture to which it would be difficult to give any degree of probability.

CXLVI. *Of the theory of syncope.* If we consider the action of the heart on the brain, we are naturally led to admit its necessity to the maintenance of life, and to deduce from its momentary suspension, the theory of syncope. Several authors have attempted to explain the manner in which their proximate cause operates, but as not one of them has gone upon facts ascertained by experience, their explanations do not at all agree with what is learnt from observing the phenomena of these diseases.

To satisfy one self, that the momentary cessation of the action of the heart on the brain, is the immediate cause of syncope, one need but read, with attention, the chapter which Cullen, in his work on the practice of physic, has devoted to the consideration of this kind of affection. It will be readily understood, that their occasional causes, the varieties of which determine their different kinds, exist in the heart or great blood vessels, or act on the epigastric centre, and affect the brain only in a secondary manner. Thus the kinds of syncope occasioned by aneurismal dilatations of the heart and great vessels, by polypous concretions formed in these passages, by ossification of their parietes or of their valves, evidently depend on the extreme debility, or on the entire cessation of the action of the heart and arteries. Their parietes, ossified, dilated, adhering to the neighbouring parts, or compressed by any fluid whatever, no longer act on the blood with sufficient force, or else this fluid is interrupted, in its progress, by some obstacle within its canal, as a polypous concretion, an ossified and immoveable valve. Cullen, very justly, termed these, idiopathic or cardiac syncopes.

To the above may be added plethoric syncope, depending on a congestion of blood in the cavities of the heart: the contractions of this organ become more frequent, it struggles to part with this excess of blood, which is injurious to the performance of its functions; but to this unusual excitement by which the contractility of its fibres is exhausted, there succeeds a kind of paralysis necessarily accompanied by syncope.

One may, likewise, include the fainting attending copious blood-letting; the rapid detraction of a certain quantity of the vivifying principle, deprives the heart of the stimulus necessary to keep up its action. The same effect is produced by drawing off the water contained in the abdomen, in ascites: a considerable number of vessels cease to be compressed; the blood which they before refused to transmit, is sent to them in profusion; the quantity sent to the brain by the heart is lessened, in the same proportion, and becomes insufficient for its excitement. Among the syncopes, called idiopathic, one may enumerate those occurring in the last stage of the scurvy, the principal character of which is, an excessive debility of the muscles employed in the vital functions, and in voluntary motion; lastly, we may add asphyxia from strangulation, from drowning, and from the gases unfit for respiration; affections in which the blood being deprived of the principle which enables it to determine the contractions of the heart, the circulation becomes interrupted. If the blood loses, by slow degrees, its stimulating qualities, the action of the heart gradually weakened, impels towards the brain a blood which, by its qualities, partakes of the nature of venous blood, and which, like it, cannot preserve the natural economy of the brain. It was thought, that by injecting a few bubbles of air into the jugular vein of a dog, one might occasion in the animal, immediate syncope, and that it was even sufficient to deprive it of life; but the late experiments of M. Nysten have proved, that the atmospherical air produces these bad effects, only when injected in a quantity sufficient to distend, in excess, the cavities of the heart, or when by being injected into the arteries, it compresses the brain. When injected only in a small quantity, the gas dissolved in the venous blood, is conveyed along with it, to the lungs, and is thence exhaled in respiration.

A second class of occasional causes consists of those which, by acting on the epigastric centre, determine, by sympathy, a cessation of the pulsations of the heart and the syncope necessarily attending this cessation. Such are the violent emotions of the soul, terror, an excess of joy, an irresistible aversion to certain kinds of food, the dread which is felt on the unexpected sight of an object, the disagreeable impression occasioned by certain odours, &c. In all these cases, there is felt, in the region of the diaphragm an inward sensation of a certain degree of emotion. From the solar plexus of the great sympathetic nerve, which, according to the general opinion, is considered as the seat of this sensation, its effects extend to the other abdominal and thoracic plexuses. The heart, the greater part of whose nerves arise from the great sympathetic, is particularly affected by this sensation. Its action is, at times, merely disturbed by it, and at others wholly suspended. The pulse becomes insensible, the countenance pale, the extremities cold, and syncope ensues. This is the course of things, when a narcotic or poisonous substance has been taken into the stomach; when this viscus is much debilitated, in consequence of long fasting, or when it contains indigestible substances; in colic, and in hysterical affections.

This last class of occasional causes do not act directly, and produce syncope only at a distant period; but the result is always the same. It happens, in all these cases, that as the arteries of the head no longer receive as much blood, as in health, the brain falls into a kind of collapse which occasions a momentary cessation of the intellectual faculties, of the vital functions, and of voluntary motion.

Morgagni, in treating of diseases, according to their anatomical order, ranks lypothymia among the affections of the chest, because the viscera contained in that cavity, shew marks of organic affection, in persons who, during life, were subject to frequent fainting.

The compression of the brain, by a fluid effused on the dura mater, in wounds of the head, does not produce real syncope, but rather a state of stupor. All causes acting, in this manner, on the brain, produce comatose and even apoplectic affections. When a man, on being exasperated, falls into a violent and sudden fit of passion, his face becomes flushed, and he is affected with vertigo and fainting. There is no loss of colour, no loss of pulse, the latter, on the contrary, generally beats with more force. This is not syncope, but the firt stage of apoplexy, occasioned by the mechanical pressure on the brain, towards which the blood is carried suddenly and in too great a quantity.

I might support this theory of syncope, by additional proofs drawn from the circumstances which favour the action of the causes giving rise to affections of this kind. For instance, syncope comes on, almost always, when we are in an erect posture, and in such a case, it is right to lay the patient in an horizontal posture. Patients debilitated by long diseases, faint the moment they attempt to rise, and recover on returning to the recumbent posture. Now, how are we to explain this effect of standing, in persons in whom the mass of humours is much impoverished, and whose organic action is extremely languid, unless by the greater difficulty to the return of the blood, from the more depending parts, and on the difficulty in ascending, of that which the contractions of the heart send towards the head? The phenomena of the circulation, are, under such circumstances, more subject to the laws of hydraulics, than when the body is in a state of health; the living solid yields more easily to the laws of physics and mechanics, and, according to the sublime idea of the father of physic, our individual nature approaches the more to universal nature.

CXLVII. *Of the motions of the brain.* Are the alternate motions of elevation and depression seen, when the brain is exposed, exclusively isochronous to the pulsations of the heart and arteries, or do they correspond, at the same time, to those of respiration? Such is the physiological problem of which I am about to attempt the solution.

Those authors who admit the existence of motions in the dura mater, do not agree as to the cause which produces them. Some, and among others, Willis and Baglivi, thought they had discovered muscular fibres, and ascribed these motions to their action: others, as Fallopius and Bauhinus, attributed these motions to the pulsations of the arteries of that membrane. The dura mater possesses no contractile power; its firm adhesion to the inside of the skull, would, besides, prevent any such motion. The motion observed in this membrane is not occasioned by the action of its vessels, for, as Lorry observes, the arteries of the stomach, of the intestines, and of the bladder, do not communicate any motion to the parietes of these hollow viscera, and yet, in number and size, they, at least, equal the menyngeal arteries.

The motion observed in the dura mater is communicated to it by the cerebral mass which this membrane covers; and this opinion of Galen, adopted by the greater number of anatomists, has been placed beyond a doubt, by the the experiments of Schlitting, of Lamure, Haller and Vicq-d'Azyr. They have all observed, that on removing the dura mater, the brain continued to rise and fall, and with the exception of Schlitting, they agreed that the brain, absolutely, passive, received from its vessels, the motions in which the dura mater partook: but are these motions communicated by the arteries or by the cerebral veins, and by the sinuses in which these terminate, or, in other words, are they isochronous, to the beats of the pulse, or to the contraction and successive dilatation of the chest, during respiration.

Galen, in his treatise on this function, says, that the air admitted into the pulmonary organ distends the diaphragm, and its conveyed, along the vertebral canal, into the skull. According to this writer, the brain rises during the enlargement of the chest, and it sinks, on the contrary, when the parietes of this cavity are brought nearer to its axis. Schlitting, in a memoir presented to the Academy of Sciences, towards the middle of the last century, maintains that these motions take place, in a different order, the elevation of the brain corresponding to expiration, and its depression to inspiration Conceiving that he has determined this fact, by a sufficient number of experiments, he does not enter into any explanation, and concludes his enquiry, by asking whether the motions of the brain are occasioned by the afflux of air, or of blood, towards that organ.

Haller and Lamure attempted to answer this difficulty. They both performed a number of experiments on living animals, acknowledged the fact observed by Schlitting, and explained it in the following manner: As well as this last anatomist, Lamure believed that there is a vacuum between the dura and pia mater, by means of which, the motions of the brain might always be performed. The existence of such a vacuum is disproved by the close contact of the membranes between which it is supposed to exist.

During expiration, continues Lamure, the parietes of the chest close on themselves, and lessen the extent of this cavity. The lungs, pressed in every direction, collapse; the curvature of their vessels increases, and the blood flows, along them, with difficulty. The heart and great vessels thus compressed, the blood carried by the upper vena cava to the right auricle, cannot be freely poured into this cavity which empties itself, with difficulty, into the right ventricle, whose blood is unable to penetrate through the pulmonary tissue. On the other hand, as the lungs compress the vena cava, a regurgitation takes place of the blood which it was conveying to the heart; forced back along the jugulars and vertebrals, it distends these vessels, the sinus of the dura mater which empty themselves into them, and the veins of the brain which terminate into these sinuses. Their distention accounts for the elevation of the cerebral mass soon followed by depression, when, on inspiration succeeding expiration, and on the lungs dilating, the blood which fills the right cavities of the heart, can freely penetrate into the pulmonary substance, and make way for that which the vena cava is bringing from the superior parts of the body.

Haller considered this reflux as very difficult, the blood having to rise against its own gravity, and he admitted Lamure's explanation, only in the forcible acts of respiration, as in coughing, laughing, and sneezing. He maintained that, in a state of health, there is to be observed, during expiration, a mere stagnation of the blood, in the vessels which bring it from the internal parts of the skull. He further admits, on the testimony of a great number of authors, another order of motions depending on the pulsations of its arteries; so that, according to Haller, the cerebral mass is incessantly affected by motions, some of which depend on respiration, while the others are quite independant of it.

Lastly, according to Vicq d'Azyr, the brain, on being exposed, presents a double motion, or rather two kinds of motion from without; the one from the arteries and which is least remarkable, the other from the alternate motions of respiration.

CXLVIII. This opposition between authors of reputation, and whose theories have, in general, been adopted, induced me to repeat the experiments which each of them brings in support of his own opinion, and to perform further experiments on this subject. My investigation soon convinced me, that these authors had given a statement of their opinions, and not of the fact itself. In fact, the alternate motions of elevation and depression observed in the brain, are isochronous to the systole and diastole of the arteries at its base. The elevation of the brain corresponds to the dilatation of these vessels, its depression to their contractions. The process of respiration has nothing to do with this phenomenon, and even, admitting the stagnation or the regurgitation of the blood in the jugular veins, the arrangement of the veins, within the skull, is such, that this stagnation or reflux could not produce alternate motions of the cerebral mass.

The brain receives its arteries from the carotids and vertebrals, after they have entered the skull, the former along the carotid canals, the latter through the foramen magnum of the occipital bone. It would be useless to describe their numerous divisions, their frequent anastomoses, the arterial circle, or rather polygon formed by these anastomoses, and by means of which, the carotid and vertebral arteries communicate together, by the side of the sella turcica. Haller has given a very correct view and an excellent description of this part*. The account of the internal carotid artery published by that great anatomist is, according to Vicq d'Azyr, a chef-d'œuvre of learning and precision; the same encomium might be bestowed on the latter who gave a superb drawing of the same part. I shall content myself with observing, that the principal arterial trunks going to the brain, are situated at the base of this viscus; that the branches into which these trunks divide, and the subdivisions of these branches, are, likewise, lodged at its base in a number of depressions, and that, in the last place, the arteries of the brain do not penetrate into its substance, till after they have undergone in the tissue of the pia mater, which appears completely vascular, very minute subdivisions.

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* Fasciculi anatomici. F. 7. tab. 1.

The vessels which return the portion of blood which has not been employed in the nutrition and growth of the brain, are, on the contrary, situated towards its upper part, between its convex surface, and the arch of the cranium, each convolution contains a great vein which opens into the superior longitudinal sinus. The vena Galeni which deposits into the sinus, the blood brought from the choroid plexus; small veins which open into the carvernous sinuses; others, likewise very minute, which passing through the foramina in the alæ majores of the sphenoid bone, contribute to form the venous plexus of the zygomatic fossa, are the only exceptions to this general rule.

This being laid down on the arrangement of the arteries and veins, let us examine what will be the effect of their action, with regard to this viscus.

The contractions of the heart propel the blood into the arterial tubes, which experience especially at the place of their curvatures, a manifest displacement, at the time of their dilatation. All the arteries situated at the base of the brain, experience both these effects at once. Their united efforts communicate to it a motion of elevation succeeded by depression, when, by their contraction, they re-act on the blood which fills them.

These motions take place, only as long as the skull remains entire; this cavity is too accurately filled, and there is no void space between the membranes of the brain. Lorry who, with good reason, denied the existence of such a space, committed an equally serious anatomical mistake in asserting, that as no motion could take place, on account of the state of fulness of the skull, it was effected in the ventricles, which he considers as real cavities, but which, as Haller has shewn, are when in a natural state, merely surfaces in contact. No motion actually takes place, except in those cases in which there is a loss of substance in the parietes of the skull.

It is easy to conceive, however, that the brain which is soft and of weak consistence, yields to the gentle pressure of its arterial vessels. Does not this continued action of the heart on the brain, explain, in a satisfactory manner, the remarkable sympathy between those two organs, linked by such close connections? It is, besides, of very manifest utility, and connected with the return of the blood distributed to the cerebral mass and to its envelopes. The veins which bring it back, alternately compressed against the arch of the skull, empty themselves more easily into the sinuses of the dura mater, towards which their course is retrograde, and unfavourable to the circulation of the blood which they pour into them.

When any thing impedes the free passage of the blood through the lungs, it stagnates in the right cavities of the heart; the superior vena cava, the internal jugulars, and consequently the sinuses of the dura mater, and the veins of the brain which terminate in them, are gradually distended; and if this dilatation were carried to a certain degree, the veins of the brain, placed between it and the arch of the skull, would tend to depress it towards the base of that cavity. If this dilatation, at first slight, were carried be-beyond the extensibility of these vessels, their rupture would occasion fatal effusions. It is in this manner, that some authors have explained sanguineous apoplexy.

It will be objected perhaps, that many of the sinuses of the dura mater are at the base of the skull, and that, consequently, their dilatation must tend to raise the cerebral mass.

But the greater part of these sinuses are connected only with the cerebellum and the medulla oblongata, of which it has not yet been possible to ascertain the motions. These sinuses are almost all lodged in the edges of the falx and of the tentorium cerebelli. The cavernous sinus in which the ophthalmic vein disgorges itself, the communicating sinuses which allow the blood of one of these sinuses to pass into the other, are too insignificant to produce a raising of the cerebral mass. Lastly, the resistance of their parietes, formed chiefly by the dura mater, must set strait bounds to their dilatation; the spungy tissue which fills the interior of the cavernous sinuses, still makes this dilatation and the reflux of the blood more difficult.

CXLIX. It is not enough to prove, by reasons drawn from the disposition of parts, that the motions of the brain are communicated to it, by the collection of arteries at its base; the fact must yet be established upon observation, and placed beyond doubt, by positive experiments. The following are what I have attempted for this purpose:

A. I have first repeated the observation of some authors, and ascertained, as they did, that the pulsations felt on placing the finger on the fontanels of the skulls of new-born infants, correspond perfectly to the beatings of the heart and arteries.

B. A patient, trepanned for fracture, with effusion on the dura mater, enabled me to see the brain, alternately rising and falling. The rising corresponded with the diastole, the falling with the systole of the arteries.

C. Two dogs, trepanned, exhibited the same phenomenon, in the same relation, to the dilatation and contraction of the arteries.

D. I removed, carefully, the arch of the skull, on the body of an adult. The dura mater, disengaged from its adhesions to the bones which it lines, was preserved, perfectly untouched. I afterwards laid bare the main carotids, and injected them with water. At every stroke of the piston, the brain shewed a very sensible motion of rising, especially when the injection was forced at once along the two carotids.

E. I have injected the internal jugular veins. The cerebral mass remained motionless. Only the veins of the brain, the sinuses of the dura mater dilated. The injection having been kept up for some time, there resulted from it a slight swelling of the brain: when driven with more force, some of the veins burst, and the liquor flowed out. The same injection being made with water strongly reddened, the surface of the brain became coloured with an intense red. To see clearly this effect, you ought, after removing the arch of the skull, to divide, on each side, the dura mater, on a level with the circular incision of the skull, then turn back the flaps towards the upper longitudinal sinus.

F. The internal jugular veins having been laid open, while the injection was forced along the main carotids, each time the piston was pushed forward, the venous blood flowed with the greatest impetus; a clear proof of the manifest influence of the motions of the brain, on the course of the blood in its veins, and in the sinuses of the dura mater.—This experiment had been already performed by other anatomists, and amongst others, by Ruysch, with a view of proving the immediate communication between the arteries and veins. This communication, which is, at present, universally acknowledged, may be proved by other facts. This one is evidently any thing but conclusive.

G. In a trepanned dog, I tied successively the two carotids. The motions of the brain abated, but did not cease. The anastomoses of the vertebrals, with the branches of the carotids, account for this phenomenon.

H. I took a rabbit, a gentle creature, easy to confine, and very well adapted for difficult experiments: after laying bare the brain, and observing that its motions were simultaneous to the beats of the heart, I tied the trunk of the ascending aorta: the moment the blood ceased rising to the head, the brain ceased moving, and the animal died.

I. The tying of the internal jugular veins, did not stop the motions of the brain; but its veins dilated, and its surface, bared by the removal of a flap of the dura mater, was sensibly redder than in the natural state. The dog became affected with stupor, and expired in convulsions.

The opening of these veins did not hinder the continuance of the motions; they grew fainter only when the animal was weakened by loss of blood.

K. The opening of the superior longitudinal sinus, the only one that could easily be opened, did not weaken the motions of the brain. It is observed that the blood flows out more freely from it, during the elevation.

L. The compression of the thorax, on human bodies, produces but a slight reflux in the jugular veins, especially, if, during this compression, the trunk is kept raised. The reflux is greater, when the trunk is laid flat.

These experiments might be varied and multiplied; if, for instance, the injection were thrown, at once, along the vertebral arteries, and the internal carotids: but those I have stated are sufficient for my purpose.

Since the first publication of this enquiry, in the Memoirs of the Medical Society,* I have had many opportunities of repeating the observations and experiments, which serve as a foundation to the theory there detailed. Among the facts which confirm this theory, there is one that appears to me worth stating: it would be sufficient by itself, if it were possible to establish a theory on the observation of a single fact. A woman, about fifty years of age, had an extensive carious affection of the skull; the left parietal bone was destroyed, in the greatest part of its extent, and left uncovered a pretty considerable portion of the dura mater. Nothing was easier than to ascertain the existence of a complete correspondence, between the motions of the brain and the beats of the pulse. I desired the patient to cough, to suspend her respiration suddenly, the motions continued in the same relation to each other; when she coughed, the head was shaken, and the general concussion, in which the brain partook, might have been mistaken by a prejudiced observer, for the proper motions of that organ, and depending on the reflux of blood in the veins.

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* Mémoires de la Société Médicale de Paris, an VII. troiseme année, pag. 197, *et suiv.*

In experiments on dogs, the same motion takes place, when the animal barks, but it is easy to perceive, that the concussion affecting the brain is experienced by the whole body, and that the effort of expiration, in barking, causes a concussion more or less violent.

The patient, mentioned in the preceding observation, died about a month after I came to the Hospital of St. Louis, in which she had been for a considerable length of time. On opening the body, the left lobe of the brain was found softened and in a kind of putrid state? the ichor which was formed, in considerable quantity, flowed outwardly, by a fistulous opening in the dura mater whose tissue was rather thickened.

CL. The slight consistence of the brain, which Lorry considers as favourable to the communication of the motion which its arteries impart to it, appears to me to be against this transmission. In fact, the dilated vessels not being able to depress the base of the skull on which they rest, make their effort against the cerebral mass, and raise it the more easily (the arch of the skull being removed) from its presenting a certain resistance. If the brain were too soft, the artery would merely swell into it, and would not lift it. To satisfy one's self of this truth, one need only observe what happens when the posterior part of the knee rests on a pillow, or on any thing of the same sort; then, the motions which the popliteal artery impresses on the limb, are but little apparent; but they become very visible, if the ham rests on any thing that resists the action on the other knee, for instance:—then the artery, which cannot depress it, exerts its whole action in raising the lower extremity: which it does, the more easily, from acting against a bony, resisting, and hard part. This experiment completely invalidates the opinion of Lorry. The want of analogy will not be objected: it will not be said that the brain is heavier than the lower extremity, nor that the sum of the calibers of the internal carotid and the vertebral arteries, is not greater than that of the popliteal artery.

This continual tendency of the brain to rise, produces in the end, on the bones of the skull which resist this motion, very marked effects. Thus, the interior surface of these bones, smooth, in early life, becomes furrowed with depressions, the deeper as we advance in age. The digital depressions and the mammillary processes, corresponding to the convolutions and windings of the brain, are very evidently the result of its action on the enclosing parietes. Sometimes it happens that, at a very advanced age, the bones of the skull are so thinned by this internal action, that the pulsations of the brain become perceptible through the hairy scalp.

No doubt, the same cause hastens the destruction of the skull by the fangous tumours of the dura mater. The effort from expansion of the tumour, which developes itself, is further added, and makes the waste of the bones more rapid. At the end of a few months, the tumour projects outwardly, with pulsations plainly simultaneous to the beatings of the pulse, as Louis observes in a Memoir inserted among those of the Academy of Surgery.

I have shewn (CXLVIII) that the disposition of the veins of the brain and of the sinuses of the dura mater was adverse to the action ascribed to them, on this viscus. Experiment (E. L.) shews that the stagnation of the blood, or even its regurgitation, could produce only a slow and gradual distension of the sinuses of the dura mater, and veins terminating in it, with a silght turgescence of the cerebral mass, if the cause, producing the stagnation of the blood or its reflux, prolonged its action to a partial destruction of the skull.

Lastly, the alternate motions of the brain, said to correspond to those of respiration, ought to be to the beats of the pulse, in the ordinary ratio of 1 to 5. On the contrary, it is easy to satisfy one's self that these motions are in an inverse ratio, and perfectly simultaneous to the pulsations of the heart and arteries.

The results of the experiments I have stated in that Memoir, compared to those obtained by justly-celebrated inquirers, are too remarkably different not to have induced me to make some attempt at investigating the cause of our disagreement. For that purpose, I thought it necesary to examine scrúpulously all the circumstances.

The work of Lamure contains anatomical errors, which throw suspicions upon his accuracy. Haller did not himself make the experiments of which he speaks, in treating of the influence of respiration on the circulation of venous blood. This article is drawn from a thesis defended at Göttingen by one of his disciples. Lastly, Vicq-d'Azyr attempted no confirming experiment, and seems to have had in view only the reconciling all opinions.

No one of these anatomists has distinguished the motions of elevation impressed on the cerebral mass by the impulse of its arteries, from the swelling of the sinuses of the dura mater, of the veins distributed to it, and from the tumefaction of the brain which may be caused by difficult respiration. This mistake would be the more easy, as animals tortured by the knife of the anatomist, breathe painfully, convulsively, and at shorter intervals than in their natural state. Schlitting, the first author of these experiments, appears especially to have confounded the motion of rising, the real displacement of the brain, with the turgescence of this viscus. At every expiration, he says, I have seen the brain rise, that is to say, swell, and at every inspiration I have seen it fall, that is to say, collapse.

"*Toties animadverti perspicuè—in omni expiratione, cerebrum universum ascendere, id est intumescere; atque in quâvis inspiratione illud descendere, id est detumescere.*"

We may, therefore, consider as a truth strictly demonstrated by observation, experiment, and reasoning, the following proposition:—

The motions observable in the brain, when laid bare, are imparted to it solely by the pulsations of the arteries at its base, and are perfectly simultaneous to the pulsations of these vessels: further, the reflux and stagnation of the venous blood, are able to swell its substance.

CLI. *Action of the nerves and brain.* It is undoubtedly, as Vicq-d'Azyr has said, by a motion of some sort that the nerves act. Setting out from this simple idea, one may admit several kinds of nervous motions, the one operating from the circumference to the centre, it is the motion of sensation which we are about more particularly to study in this paragraph; the other, acting from the centre to the circumference, and this motion, produced by the will, determines the action of the muscular organs, &c.

In what manner are the impressions produced on the senses by the bodies which surround us, transmitted, along the nerves, to the brain? Is it through the intervention of a very subtle fluid, or can the nerves, as has been stated by some physiologists, be considered as vibrating cords? This last idea is so absurd, that one cannot help wondering it should so long have been in vogue. A cord that it may vibrate, must be in a state of tension, along the whole of its length, and fixed at both extremities. The nerves are not in a state of tension, their extremities, in no degree fixed, approach towards each other or recede according to the difference of position, the tension, the turgescence, the fulness or collapse of parts, and vary constantly intheir distance from each other. Besides, the nervous cords, situated between pulps, at their origin, and at their termination, cannot be extended between these two points. The nervous fibre is the softest, the least elastic of all the animal fibres; when a nerve is divided its two extremities, far from receding by contracting, project, on the contrary, beyond each other; the point of section shews a number of small granulations of medullary and nervous substance, which flows through its minute membranous canals. Surrounded by parts to which they are, to a certain degree, united, the nerves could not vibrate; Lastly, admitting the possibility of their being capable of vibrating, the vibration of a single filament ought to bring on that of all the rest, and carry confusion and disorder in every motion and sensation.

It is much more probable that the nerves act by means of subtle, invisible, and impalpable fluid, to which the ancients gave the name of animal spirits; this fluid, unknown in its nature, and to be judged of only by its effects, must be wonderfully minute, since it eludes all our means of investigation. Does it entirely proceed from the brain, or is it equally secreted, by the membranous envelopes of each nervous filament? (*Neurilèmes*, Reil.) To say the truth, one can bring no other proof of the existence of a nervous fluid, but the facility with which, by means of it, we are enabled to explain the various phenomena of sensation, and its utility in explaining these phenomena. These proofs, however, may not appear completely satisfactory to those who are very strict, and who do not consider as proved what is merely probable.

Among the constituent principles of the atmosphere, there are generally diffused several fluids, such as the magnetic and electric fluids. Might not these fluids, on entering with the air into the lungs, combine with the arterial blood, and be conveyed, by means of it, to the brain or to the other organs? Does not the vital action impart to them new qualities, by making them undergo unknown combinations? Do caloric and oxygen enter into these combinations which endow fluids with a certain vitality, and produce on them important changes, and which are not understood?* Have not these conjectures acquired a certain degree of probability, since the analogy of galvanism to electricity, at first supposed by the author of this discovery, has been confirmed, by the very curious experiments of Volta, repeated, commented, and explained, by all the natural philosophers of the present day, in Europe.**

The action of the nervous fluid takes place, from the extremity of nerves towards the brain, so as to produce the phenomena of sensation, for, when the nerves are tied, the parts below the ligature lose the power of sensation, while, as will be seen in the proper place, this action is propagated from the brain towards the nervous extremities, and from the centre to the circumference, in producing motions of every kind. This double current, in contrary directions, may take place in the same nerves, and it is not necessary to arrange the nerves into two classes of sensation and of motion.

All the impressions received by the organs of sense, and by the sentient extremities of nerves, are transmitted to the cerebral mass. The brain is, therefore, the centre of animal life; all sensations are carried to it; it is the spring of all voluntary motion; this centre is to the functions of relation, as the heart to the functions of nutrition. One may say of the brain, as of the heart, *omnibus dat et ab omnibus accipit.* It receives from all, and gives to all.

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* Were it not for these changes, electricity, magnetism, and galvanism, would suffice to restore life to an animal recently dead.

** Galvanism, as yet, has not realized the expectations of physiologists. Chemistry has derived the greatest advantages from it.—It is, at present, with M. M. Davy, Thenard and Gay-Lussac, the most powerful agent in the analysis of certain bodies.

The existence of a centre, to which all the sensations are carried, and from which all motions spring, is necessary to the unity of a thinking being, and to the harmony of the intellectual functions. But is this seat of the principle of motion and of sensation, circumscribed within the narrow limits of a mathematical point, or rather should it not be considered as diffused over nearly the whole brain? The latter appears to me the more probable opinion; were it otherwise, what could be the use of those divisions of the organ into several internal internal cavities; what could be the use of those prominences all varying in their form; and of the arrangement of the two substances which enter into their structure? We may conjecture, with considerable probability, that each perception, each class of ideas, each faculty, is assigned to some peculiar part of the brain. It is, indeed, impossible to determine the peculiar functions of each part of the organ; to say what purpose is served by the ventricles, what is the use of the commissures, what takes place in the peduncles; but it is impossible to study an arrangement of such combination, and to believe that it is without design, and that this division of the cerebral mass, into so many parts, so distinct, and of such various forms, is not relative to the different function, which each has to fill in the process of thought. That ingenious comparison, mentioned in the panegyric of Mery, by Fontenelle, is very applicable to the brain. "We anatomists," he once said to me, "are like the porters in Paris, who are acquainted with the narrowest and most distant streets, but who know nothing of what takes place in the houses."—What then are we to think of the system of Gall, and of his division of the outside of the skull into several compartments, which, according to the depression or projection of the osseous case, indicate the absence or the presence of certain faculties, moral or intellectual? I cannot help thinking, that this physiological doctrine of the functions of the brain, resting on too few well observed facts, is frivolous; while his anatomical discoveries on the anatomy of this organ, and on the nervous system, are of the highest importance, and well founded.

CLII. *Analysis of the Understanding.* In vain were the organs of sense laid open to all impressions of surrounding objects; in vain were their nerves fitted for their transmission: these impressions were to us as if they had never been, were there not provided a seat of consciousness in the brain. For it is there, that every sensation is felt; light and sound, and odour, and taste, are not felt in the organs they impress; it is the sensitive centre that sees, and hears, and smells, and tastes. You have only to interrupt, by compression of the nerves, the communication between the organs and the brain, and all consciousness of the impressions of objects, all sensation is suspended.

The torturing pains of a whitlow cease, if you bind the arm so strongly as to compress the nerve which carries the sensation to the brain. A living animal, under experiment, suffers nothing from the most cruel laceration, if you have first cut the nerves of the parts on which you are operating. To conclude, the organs of sense, and the nerves which communicate between them and the brain, shall have suffered no injury, shall be in a perfect state for receiving and transmitting the sensitive impression, yet no phenomena of sensation can take place, if the brain be diseased: when it is compressed, for instance, by a collection of fluid, or by a splinter from the skull in a wound of the head. This organ is, therefore, the immediate instrument of sensations, of which impressions made on the others are only the occasional causes.—This modification of sensibility, which serves to establish the relations of the living being, with objects without, would be correctly denominated *cerebral sensibility*; but that even in animals without brain, or distinct nervous system, it is very manifest. The sensibility, in virtue of which the polypus dilates his cavity, for the admission of his prey, and contracts itself to retain it, is in fact, quite distinct from that *sensibility of nutrition*, by which its substance is enabled to take to itself nutritious juices.

The brain, as Cabanis has well expressed it, acts upon the impression transmitted by the nerves, as the stomach upon the aliments it receives by the œsophagus: it does, in its own way, digest them: set in motion by the impulse it receives, it begins to re-act; and that re-action is the *perceptive sensation*, or perception.—From that moment, the impression becomes an idea, it enters as an element into thought; and becomes subject to the various combinations that are necessary to the phenomena of understanding.*

CLIII. Our sensations are nothing but modifications of our being; they are not qualities of the objects: no body has colour to the blind from birth: the rose has lost its most precious quality to him who has lost his smell: he knows it from the anemone, only by its colour, its figure, &c. We perceive nothing but within ourselves. It is only by habit, only by applying different senses to the examination of the same object, that we are at last able to separate it from our own existence; to conceive of it as distinct from ourselves, and from the other bodies with which we are acquainted; in a word, to refer to outward objects the sensations that take place within ourselves. Our ideas come to us, only by the senses; there are none innate as was imagined till the time of Locke, who has allotted to the refutation of this error a large part of his valuable work on the Human Understanding. The child that opens its eyes to the light, is prepared for the acquisition of ideas, by this merely that it has senses; that is, that it is susceptible of impressions from the objects that surround it.

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* I ought to observe, that the terms thought and understanding are, in my opinion, synonymous; both are alike, an abridged expression of the whole of the operations of the sensitive centre.

It is inaccurate, however, to compare, as some philosophers have done, the brain of a child new-born to a blank tablet, on which are to be figured all the future acts of his intelligence. If sensation came only from without, if the external senses were the only organs that could send impressions to the cerebral centre, the understanding, at the moment of birth, had indeed been nothing, and the comparison of its organ to a sheet of white paper, or to a slab of Parian marble, on which not a character were drawn, had been perfectly correct. But we are compelled to acknowledge with Cabanis, two sources of ideas quite distinct from each other, the external senses, and the internal organs. These inward sensations, springing from functions that are carrying on within us, are the cause of those instinctive determinations by which the new-born child seizes the nipple of its mother, and sucks the milk by a very complicated process, which directs the young of animals the moment after birth, and sometimes in the very act of birth, while their limbs are yet engaged in the vagina, to seize upon the dug of their dam. Instinct, as the author just quoted has very justly observed, springs from impressions received by the interior organs, whilst reasoning is the produce of external sensations; and the etymology of the word instinct, composed of two Greek words, signifying "to prick," &c. "within," agrees with the meaning we assign to it.

These two parts of the understanding, reason and instinct, unite and blend together, to produce the intellectual system, and the various determinations of mental action. But the part that each bears in the generation of ideas, is very different in animals, whose grosser external senses allow instinct to predominate; and in man, in whom the perfection of these senses, and the art of signs, which perpetuate the transient thought, augment the power of reason, while they enfeeble instinct. It is easy to conceive, that the brain, assailed by a crowd of impressions from without, will regard less attentively, and therefore suffer to escape the greater part of those that result from internal excitation. Instinct is more vigorous in savage man, and its relative perfection is his compensation for the advantages which superior reason brings to man in civilization. The moral and intellectual system of the individual, considered at different periods of life, owes more to internal sensation, the less it is advanced; for, instinct declines as reason is strengthened and enlarged.

Thus, though all the phenomena of understanding have their source in physical sensibility, this sensibility being set in action by two sorts of impressions, the brain of an infant just born, has already the consciousness of those which spring from the internal motion, and it is from these impressions that it executes certain spontaneous movements, of which Locke and his followers could find no explanation: accordingly, the partizans of innate ideas, looked upon them as the strongest confirmation of their system: but these ideas, anterior to all action of outward objects on the senses, are simple, few, and extending to a very small number of wants; the child is but a few hours old, and already it expresses a multitude of sensations, that throng upon it from the instant of its birth, sensations, which have passed to the brain, combined themselves there, and entered into the action of the will, with a velocity which equals, if it does not surpass, that of light.

It is only, after laying down between the sources of our knowledge, a very exact line of demarcation, after scrupulously distinguishing the rational from the instinctive determinations, acknowledging that age, sex, temperament, health, disease, climate, and habit, which modify our physical organization, must, by a secondary effect modify these last, that we can possibly understand the diversity of humours, of opinions, of characters, and of genius. He who has well appreciated the effect, on the judgment and reason, of the sensations that spring from the habitual state of the internal organs, sees easily the origin of those everlasting disputes on the distinction between the sensitive and the rational soul; why some philosophers have believed man solicited for ever by a good or an evil genius; spirits which they have personified under the names of Oromazes, and Arimanes, betwixt whom they imagined eternal war; the contest of the soul with the senses, of the spirit with the flesh, of the concupiscent and irascible with the intellectual principle, that contradiction which St. Paul laboured under, when he said in his Epistle to the Romans, that his members were in open war with his reason. These phenomena which suggest the conception of a two-fold being (*Homo duplex*, Buffon), are nothing but a necessary strife betwixt the determinations of instinct and the determinations of reason; between the often times imperious wants of the organic nature, and the judgment which keeps them under, or deliberates on the means of satisfying them, without offending received ideas of fitness, of duty, of religion, &c.

CLIV. A being, absolutely destitute of sensitive organs, would possess only the existence of vegetation: if one sense were added, he would not yet possess understanding, because, as Condillac has shewn, the impressions produced on this only sense, would not admit of comparison; it would all end in an inward feeling, a perception of existence, and he would believe the things which affected him to be a part of his being. The fundamental truth, so completely made out by modern metaphysicians, is found distinctly stated in the writings of Aristotle*: and there is room for surprize that that father of philosophy should have merely recognized it, without conforming to its doctrine: but, still more that it should have been for so many ages disregarded by his successors. So absolutely is sensation the source of all our knowledge, that even the measure of understanding is according to the number and perfection of the organs of sense; and that by successively depriving them of the intelligent being, we should lower, at each step, his intellectual nature; whilst the addition of a new sense to those we now possess, might lead us to a multitude of unknown sensations and ideas, would disclose to us in the beings we are concerned with, a vast variety of new relations, and would greatly enlarge the sphere of our intelligence.

The impression, produced on any organ, by the action of an outward body, does not constitute sensation; it is further requisite, that the impression be transmitted to the brain, that it be there *perceived*, that is, felt by that organ; the *sensation* then becomes

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* *Nil est in intellectu, quod non priùs fuerit in sensu.*

perception, and this first modification supposes, as is apparent, a central organ, to which the impressions on the organs may be carried. The cerebral fibres are, more or less disturbed, by the sensations sent to them, at once, from all the organs of sense; and we should acquire but confused notions of the bodies from which they proceed, if one stronger perception did not silence, as it were, the rest, and fix the *attention*. In this concentration of the soul upon a single object, the brain is feebly stirred by many sensations that leave no trace; it is thus, that after the attentive perusal of a book, we have lost the sensations that were produced by the different colour of the paper and the letters.

When a sensation is of short duration, our knowledge of it is so light, that soon there remains no remembrance of it. It is thus, that we do not perceive, every time we wink, that we pass from light to darkness, and from darkness to light. If we fix our attention on this sensation, it affects us more permanently. After occupying oneself, for a given time, with a number of things, with but moderate attention to each; after reading, for instance, a novel, full of events each of which in its turn has interested us, we finish it without being tired of it, and are surprized at the time it has taken up. It is because successive and light impressions have effaced one another, till we have forgotten all but some of the principal actions. Time ought then to appear to us to have passed rapidly; for, as Locke has well said, in his Essay on the Human Understanding, "We conceive the succession of times only by that of our thoughts."

This faculty of occupying oneself long and exclusively with the same idea, of concentrating all the intellectual faculties on one object, of bestowing on the contemplation of it alone, a lively and well supported *attention*, is found in greater or less strength in different minds: and some philosophers appear to me to have explained, very plausibly, the different capacity of different minds, the various degrees of instruction of which we are capable, by the degree of attention we are able to give to the objects of our studies.

Who, more than the man of genius, pauses on the examination of a single idea, considers it with more profound reflexion, under more aspects and relations, bestows on it, in short, more entire attention.

Attention is to be considered as an act of the will, which keeps the organ to one sensation, or prepares it for that sensation, so as to receive it more deeply. To look, is to see with attention; to listen, is to hear attentively: the smell, the taste, in the same way, are fixed upon an odour, or a flavour, so as to receive from them the fullest impression. In all these cases, the sensation may be involuntary, but the attention by which it is heightened, is an act of the will. This distinction has already been well laid down with regard to the feeling, which is only the touch exerted under the direction of the will.

According to the strength or faintness of the impression that a sensation, or an idea (which is but a sensation operated upon by the cerebral organ), has produced on the fibres of that organ, will be the liveliness and permanence of the recollection. Thus, we may have *reminiscence* of it, or recal faintly that we have been so affected; or *memory*, which is a representation of the object, with some of its characteristic attributes, as colour, bulk, &c.

The pains that appear to be felt in limbs which we have lost, have not their place in the part that is left; the brain is not deceived, when it refers to the foot, the sufferings of which the cause is in the stump, after the amputation of the leg or thigh. I have at this moment, before me, the case of a woman and of a young man, whose leg and thigh I took off for scrophulous caries, of many years standing, and incurable by any other means. The wound, from the operation, is completely cicatrised. The stump has not more sensibility than any other part covered by integuments, since it may be handled without pain. And yet, both, at intervals, and especially when the atmosphere is highly electrified, complain of pains in the limbs which they have lost some months ago. They recognize them, by certain characters; for those of their disease. They, like all perceptions, are manifestly given in charge to the memory, which reproduces them, when the cerebral organ repeats the action, once occasioned by the impressions of the disease.

Finally, if the brain is easy of excitation, and at the same time, faithful in preserving the impressions it has received, it will possess the power of bringing up ideas with all their connected and collateral ideas; of reproducing them, in some sort, by recalling the entire object, whilst memory presents us with a few of its qualities only. This creative faculty is called *imagination*. If it sometimes produces monsters, it is that the brain, by its power of associating, connecting, combining ideas, reproduces them in an order not according to nature, gathers them under capricious associations, and gives occasion to many erroneous judgments.

When the mind brings together two ideas, when it compares them, and determines on their analogy it *judges*. A certain number of *judgments*, in series, form a *reasoning*. To reason, then, is only to judge of the relations that exist among the ideas with which the senses supply us, or which are reproduced by imagination.

It is, with the faculties of the soul, as with those of the body. When called into full exertion, the intellectual organ gains vigour; it languishes in too long repose. If we exercise certain faculties only, they are greatly developed, to the prejudice of the rest. It is thus, that by the study of mathematics, soundness of judgment is acquired, and precision of reasoning: to the extinction of imagination, which never rises to great strength without injury to the judging and reasoning powers. The descriptive sciences employ especially the memory, and it is seldom that they much enlarge the minds of those who study them exclusively.

CLV. Condillac has immortalized his name, by discovering, the first, and by demonstrating irrefragably, that signs are as necessary to the formation as to the expression of ideas; that language is not less useful for thinking than for speaking; that if we could not attach the notions once acquired to received signs, they would remain always unconnected, and uncompleted, since we should have no power to associate and compare them, and to determine their relations. It is the imperfection or the total want of signs, for fixing their ideas, that makes the infancy of the lower animals perpetual. It is this that makes it impossible for them to transmit to another generation, or even to communicate one with another, the acquisitions of individual experience: which experience is indeed, by the same cause, restrained within very narrow limits, and confined to a few simple notions, a few ideas resting merely on its wants and on its powers. If there were not signs to preserve ideas, and to connect them, memory would be nothing, all impressions would be effaced, soon after they were felt, all collections of ideas would be dissolved as soon as formed, (if they could be formed at all) our ignorance would be indefinitely prolonged, and we should reach old age, with a mind still in its infancy.

When we reflect on a subject, it is not directly on the ideas, but on the words expressing them, that the mind operates; we should never have the idea of numbers, if we had not assigned distinct names to numbers, whether single or collected. Locke speaks of some Americans, who had no idea of the number thousand, because the words of their language expressed nothing beyond the number twenty. La Condamine informs us, in his narrative, that there are some who count only to three, and the word they employ to express the number is so complicated, of a pronunciation so long and difficult, that, as Condillac observed, it is not surprising, that having begun with a method so inconvenient, they have not been able to advance any further. "Deny, (says this writer), to a superior mind, the use of letters, how much of knowledge you put out "of his reach, which an ordinary capacity will attain to without "difficulty. Go on, and take from him the use of speech, the lot "of the dumb will shew you, how narrow are the limits within "which you confine him. Finally, take from him the use of all "sorts of signs, let him be unable to find the least sign for the "most ordinary thought, and you have an idiot."*

We are made acquainted by travellers with certain tribes, so backward in the art of expressing their ideas by signs, that they seem to serve as a link between civilized nations and certain species of animals, whose instinct has been perfected by education. One might even assert, that there is less distance, in respect to intelligence, from man in that extreme abasement, to the higher animals, than there is to a man of superior genius, such as Bacon, Newton, or Voltaire.

In another part of the same work, after having demonstrated, that languages are real analytic methods, that the sciences may may be reduced to well constructed languages, he shews how powerful is their influence in the cultivation of the mind. But he shall speak himself with that clearness of expression, which is the characteristic and the charm of his writings. "Languages are like the cyphers of the geometricians; they present new views to the mind, and expand it as they are brought nearer to perfection. The discoveries of Newton had been prepared for him, by the signs that had been already contrived, and the methods of calculation that had been invented. If he had arisen sooner, he might have been a great man to his own age; but he would not have been the admiration of ours. It is the same in other departments."

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* Essai sur l'origine des Connoissances humaines, sec. 4.

The most scanty languages have been formed in the most barren countries. The savage who strays along the desert shores of New Zealand, needs but few signs to distinguish the small number of objects that habitually impress his senses: the sky, the earth, the sea, fire, shells, the fish that form his chief food, the quadrupeds, and the vegetables, which are but few in number, under this severe climate, are all that he has to name and to know: accordingly his vocabulary is very small; it has been given to us by travellers in the compass of a few pages. A copious language, one capable of expressing a great variety of objects, of sensations, and of ideas, supposes high civilization in the people among whom it is spoken. You hear complaints of the perpetual recurrence of the same expressions, the same thoughts, the same images, in the poetry of Ossian: but living amidst the barren rocks of Scotland, the Bards could not speak of things, of which nothing, on the soil they inhabited, could supply them with the idea. The monotony of their languages was involved in that of their impressions, always produced by rocks, mists, winds, the billows of the ireful ocean, the gloomy heath, and the silent pine, &c. The repetition of the same expressions, in the Scriptures, shows that civilization had not made the same progress among the Hebrews, as among the Greeks and Romans. The connexion there is between the genius of a language, and the character of the people that speak it; the influence of climate, of government, and of manners on language, the reason why the great writers, in every department, appear together, at the very time in which a language reaches its perfection and maturity, &c. these are problems that suggest themselves, and would well merit our endeavous to obtain solution, did not the investigation manifestly lead beyond the limits of our inquiry.

Though Condillac has said, repeatedly, in his works, that all the operations of the soul, are merely sensation, variously transformed, that all its faculties are included in the single one of sense; his analysis of thought leaves still much doubt and uncertainty on the real character and relative importance of each of her faculties.

The merit of dispersing the mist which covered this part of metaphysics remained for M. Tracy. His Elements of *Ideology, leave

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* Elémens d' Idéologie, par M. Destutt Tracy, sénateur, Membre de l'Institut.

nothing to be wished for on this subject. I shall extract some of its main results, referring the reader for the rest to the work.

To think is only to feel; and to feel is, for us, the same as to exist; for, it is by sensation we know of our existence. Ideas, or perceptions, are either sensations, properly so called, or recollections, or relations which we perceive, or, lastly, the desire that is occasioned in us by these relations. The faculty of thought, therefore, falls into the natural subdivision of sensibility, properly termed memory, judgment, and will. To feel, properly speaking, is to be conscious of an impression; to remember, is to be sensible of the remembrance of a past impression; to judge is to feel relations among our perceptions: lastly, to will is to desire something. Of these four elements, *sensations*, *recollections*, *judgments* and *desires*, are formed all compound ideas. Attention is but an act of the will: comparison cannot be separated from judgment, since we cannot compare two objects without judging them: reasoning is only a repetition of the act of judging: to reflect, to imagine, is to compose ideas, analyzable into sensations, recollections, judgments, and desires. This sort of imagination which is only certain and faithful memory, ought not to be distinguished from it.

Finally, want, uneasiness, inquietude, desire, passions, &c. are either sensations or desires. There is room, therefore, to reproach Condillac with having divided the human mind into understanding and will only: because the first term includes actions too unlike, such as sensation, memory, judgment; and with having run into the opposite extreme, in the too great multiplication of secondary divisions.

CLVI. *Disorders of thought.* Philosophers would undoubtedly attain to a much profounder knowledge of the intellectual faculties of man, if they joined to the study of their regular and tranquil action, that of the many disordered actions to which they are liable. It is not enough, if we would understand them aright, to watch their operation when the soul is undisturbed and at ease: we must follow it in its perturbations and wanderings: we must see its powers, now separating themselves from those with which they ought to act; now combining with them under false perceptions: sometimes, altogether drooping, and sometimes starting into an extreme violence of action, of which we can neither mistake the importance nor the nature; and, as the greater part of our ideas are derived from the analogies we are able to discern among the objects that supply them, amidst these troubles of human passion and human reason, we learn to conceive more profoundly of their nature, than if we had been satisfied with observing them in the calm of their natural condition.

The observation of mania is yet too imperfect in the number, variety, and precision of its facts, to fix the classification of the species of mental alienation, according to the intellectual faculty that is disordered in each. Professor Pinel has, nevertheless, ventured to ground his distinctions of the species of mania on the labours of modern psychologists, and shown that all might be referred to five kinds, which he marks by the names of melancholy, of mania without delirium, mania with delirium, dementia, and idiotcy*. In the first four kinds, there is perversion of the mental faculties, which are in languid or excessive action. We are not to look for the cause of these derangements in vice of original conformation; for, melancholy, mania with or without delirium, and madness, scarcely ever appear before puberty. It is agreed, among observers, that almost all maniacs have become so, between twenty and forty years old: that very few have lost their reason either before or after this stormy period of life, wherein men, yielding, by turns, to the torments of love and of ambition, of fear and of hope, to the sweet illusions of happiness, and the realities of suffering, consumed with passions for ever reviving, often repressed, and rarely satisfied, feel their intellectual powers impaired, annihilated, or abased by that tempest of the moral nature, which has well been compared to the storms which, in their violence, lay desolate the flourishing earth.

We are compelled to grant, that our acquaintance with the structure of the brain and of the nerves is too imperfect, that dissections of the bodies of maniacs have been too few, and those often by physicians† too little familiar with the minute structure of the sensitive organ, to warrant us in asserting or denying, that derangement of intellect depends constantly on organic injury; though it is highly probable, many facts, at least, collected by observers, who, like Morgagni, deserve the utmost confidence, authorize the belief, that the consistence of the brain is increased in some maniacs who are distinguished by the most obstinate and unvarying adherence to their ruling ideas; that it is, on the other hand, soft, watery, and in a kind of incipient dissolution, in some others, whose incoherent ideas after their aptitude for association, and for transformation into judgments is gone, succeed one another rapidly, and seem to pass away without a trace, &c.

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* For more ample explanation I must refer to the work. *Traité médico-philosophique sur l'Aliénation mentale ou la Manie*, par P. Pinel. *Paris*, 1800.

† This censure is especially applicable to the researches of Dr. Greding.

If, in the multitude of maniacs, the organ of the understanding suffer only imperceptible injury, it is very remarkably changed in idiots. The almost entire obliteration of the intellectual faculties, which constitutes idiotcy, when it is not brought on by some strong and sudden shock, some unexpected and overwhelming emotion, breaking down at once all the springs of thought, when it is an original defect, is always connected with mal-conformation of the skull, with the constraint of the organs it encloses. These defects of organization lie, as M. Pinel observes, in the excessive smallness of the head, to the whole stature, or to the want of proportion among the different parts of the skull. Thus in the idiot, whose head is given in the work on mania (pl. 2, fig. 6.) it is only the tenth of the whole height, whilst it should be something more than a seventh, if we take the Apollo of Belvedere as the type of the ideal perfection of the human figure. An idiot, whom I occasionally see, has the ocipital extremity of the head so much contracted, that the large extremity of the oval formed by the upper face, instead of being placed at the back, as in other men, is, on the contrary, turned forwards and answers to the forehead, which itself slopes towards the sinciput. The vertical diameter of the skull is inconsiderable. The head, thus shortened from above downwards, is much flattened on the sides. The hands and feet are very small, and often cold; the genitals, on the contrary, are extremely large.

In two other children, equally idiots, and now in the hospital of St. Louis, the skull, very large behind, ends in a very contracted extremity, and the forehead is very short, and not more than two inches and a half wide, measuring from the semi-circular process which terminates, at the upper part, the temporal fossa, to the commencement of the same process on the other side. The excessive growth of the genitals is not less conspicuous; they are, in these two children, one ten, the other twelve years old, as well as in the first of whom I spoke, who is fourteen, of larger size than is commonly seen after the appearance of puberty. There is nothing to indicate that this season is attained by these three idiots.

The same excess of growth is found, more conspicuously among the cretins of the Valais, idiots who (in consequence of a weak and degraded organization) are prone to lasciviousness and the most frequent onanism.

This sort of opposition in the relative energy of the intellectual organ, and of the system of reproduction, in the developement of the brain, and that of the parts of generation, is a phenomenon which must strongly interest the curiosity and engage the attention of physiologists. Who is there unacquainted with that enervation of the understanding, that intellectual and physical debility, which indulgence in the pleasures of love brings on, if we exceed ever so little the bounds of scrupulous moderation? Castration modifies the moral character of men and animals, at least, as powerfully as their physical organization, as M. Cabanis has shewn, in treating of the influence of the sexes on the origin and growth of the moral and intellectual powers.

CLVII. Our physical, therefore, holds our moral nature under a strict and necessary dependance; our vices and our virtues, sometimes produced and often modified by social education, are frequently, too, results of organization. To the conclusive proofs which the philosopher I have just named, who is an honour to his profession, brings forward of the influence of the physical on the moral human being, I will only add a single observation. It is not, certainly, the first that has been made of the kind; but none such, I believe, has yet been published. The reader recollects, I have no doubt, the old woman of whom I have spoken in treating of the motions of the brain, which an enormous caries of the bones of the skull gave an opportunity of observing in her. I wiped off the sanious matter which covered the dura mater, and I, at the same time, questioned the patient on her situation; as she felt no pain from the compression of the cerebral mass, I pressed down lightly the pledget of lint, and on a sudden the patient, who was answering my questions rationally, stopped in the midst of a sentence: but she went on breathing and her pulse continued to beat:

I withdrew the pledget; she said nothing: I asked her if she remembered my last question: she said not. Seeing that the experiment was without pain or danger, I repeated it three times, and thrice I suspended all feeling and all intellect.

A man trepanned for a fracture of the skull, with effusion of blood and pus on the dura mater, perceived his intellectual faculties going, the consciousness of existence growing benumbed and threatening to cease, in the interval of each dressing, in proportion as the fluid collected.

There are surgical observations on wounds of the head containing several facts that may be connected with the preceding observations. There is no one who has had syncope of more or less continuance, but knows that the state is without pain or uneasiness, and leaves no consciousness of what passed whilst it lasted. It is the same after an apoplexy, a fit of epilepsy, &c.

The history of temperaments supplies us with too many examples of the strict connexion which there is between the physical organization and the intellectual and moral faculties, to leave any necessity for dwelling longer on this truth, which no one questions, but which no philosopher has yet followed into all its consequences.

CLVIII. An English writer, in a work on the history of mental alienation*, has traced, better than had before been done, the physiological history of the passions, which he looks upon as mere results of organization, ranking them among the phenomena of the animal economy, and with abstraction of any moral notion that might attach to them.

All passion is directed to the preservation of the individual or the reproduction of the species. They may be distinguished, therefore, like the functions, into two classes. In the second, we should find parental love, and all the affections that protect our kind through the helplessness of its long infancy.

But Crichton, with the greater part of metaphysicians and physiologists, appears to me not to have settled correctly the meaning that should belong to the word passion. When he gives this name to hunger, an inward painful sensation, the source of many determinations of many kinds, a powerful mover of savage and civilized man,—to the anxiety which attends the breathing an air deficient in oxygen,—to the impressions of excessive heat and cold,—to the troublesome sensation produced by the accumulation of urine and fecal matter,—to the feeling of weariness and fatigue that is left by violent exertions,—he confounds sensation with the passions or desires which may spring from it.

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* An Inquiry into the Nature and Origin of Mental Derangement—London, 1798, 2 vols, 8vo.

It is to avoid extreme wants, of which a vigilant foresight perceives afar off the possibility,—it is to satisfy all the factitious wants which society and civilization have created, that men condemn themselves to those agitations, of which honour, reputation, wealth, and power, are the uncertain aim. Our passions have not yet been analyzed with the same care as our ideas: no one has yet duly stated the differences there are, in respect to their number and energy, betwixt savage man, and man in the midst of civilized and enlightened society.

As the habitual state of the stomach, of the lungs, of the liver and internal organs, is connected with certain sets of ideas;—as every vivid sensation of joy or distress, of pleasure or pain, brings on a feeling of anxiety in the præcordia,—the ancients placed in the viscera the seat of the passions of the soul: they placed courage in the heart, anger in the liver, joy in the spleen, &c. Bacon and Van Helmont seated them in the stomach; Lecat in the nervous plexuses; other physiologists in the ganglions of the great sympathetic, &c. But have they not confounded the effect with the cause? the appetite with the passion to which it disposes? The appetites, out of which the passions spring, reside in the organs, they suppose only instinctive determinations, whilst passion carries with it the idea of intellectual exertion. Thus, the accumulation of semen in the vesiculæ which serve for its reservoirs, excites the venereal appetite, quite distinct from the passion of love, though often its determining cause. Animals have scarcely more than appetite, which differs as much from passion as instinct from intelligence. However, the brain is not to be considered as the primitive seat of the passions*, as is done by the greater number of philosophers. Of all the feelings of man, the most lasting, the most sacred, the most passionate, the least susceptible of injury from all the prejudices of the social state, maternal love, is surely not the result of any intellectual combination, of any cerebral action: it is in the bowels *(entrailles,)* its source lies; thence it springs, and all the efforts of imagination cannot attain it for those who have not been blessed with a mother's name.

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* If we analyzed the passions carefully, it would be right to distinguish those which are common to all men, which appertain to our physical wants and to our nature, from certain caprices of the mind which have been honoured with the name of passions, as avarice, ambition, erroneous calculations which should be referred to mental derangement, and classed among the different kinds of insanity.

All passion springs from desire, and supposes a certain degree of exaltation of the intellectual faculties. The shades of the passions are infinite: they might be all arranged by a systematic scale; of which indifference would be the lowest gradation, and maniacal rage the highest. A man, without passions, is as impossible to imagine, as a man without desires; yet we distinguish as passionate, those whose will rises powerfully towards one object earnestly longed for. In the delirium of the passions, we are for ever making, unconsciously, false judgments, of which the error is exaggeration. A man recovering from a seizure of fear, laughs at the object of his terror. Look at the lover whose passion is extinct! freed, at last, from the spell that enthralled him, all the perfections with which his love had invested its object are vanished; the illusion has passed away; and he can almost believe that it is she who is no longer the same, while himself alone is changed: like those maniacs who, on their return to reason, wonder at the excesses of their delirium, and listen, incredulously, to the relation of their own actions. The ambitious man feeds on imaginations of wealth and power. He who hates, exaggerates the defects of the object of his hatred, and sees crimes in his lightests faults.

The *affections* of the soul, or the passions, whether they come by the senses, or some disposition of the vital organs favour their birth and growth, may be ranged in two classes, according to their effects on the economy. Some heighten organic activity; such are joy, courage, hope, and love: whilst others slacken the motions of life, as fear, grief, and hatred. And others there are, that produce the two effects alternately, or together. So ambition, anger, despair, pity, assuming, like the other passions, an infinite variety of shades, according to the intensity of their causes, individual constitution, sex, age, &c. at times increase, at times abate the vital action, and depress or exalt the power of the organs.

The instances which establish the powerful influence of the passions on the animal economy are too frequent to need reciting. Writers, in every department, furnish such as shew that excess of pleasure, like excess of pain, joy too lively or too sudden, as grief too deep and too unexpected, may bring on the most fatal accidents and even death. Without collecting, in this place, all the observations of the sort with which books swarm, I shall content myself with referring to those who have brought together the greatest number of facts under one point of view; as Haller in his Phisiology; Tissot, in his Treatise on Diseases of the nerves; Lecamus, in his work on Diseases of the Mind; Bonnefoy, in a paper on the Passions of the Soul; inserted in the fifth volume of the Collection of Prizes, adjudged by the Academy of Surgery.

The effects of the passions are not, for their uniformity, the less inexplicable. How, and why does anger give rise to madness, to suppression of urine, to sudden death? How does fear determine paralysis, convulsions, epilepsy, &c.? Why does excessive joy, a sense of pleasure carried to extremity, produce effects as fatal as sad and afflicting impressions? In what way can violence of laughter lead to death? Excess of laughter killed the painter Zeuxis and the philosopher Chrysippus, according to the relation of Pliny. The conversion of the reformed of the Cevennes, under Louis XIV. was effected by binding them on a bench, and tickling the soles of their feet, till, overpowered by this torture, they abjured their creed: many died in the convulsions and immoderate laughter which the tickling excited. A hundred volumes would be insufficient to detail all the effects of the passions on physical man; how many would it take to tell their history, in moral man, from their dark origin, through all their stages of growth, in the infinite variety of their characters, and in all their evanescent shades!

The inquiries of Physiology are directed to the functions that are carried on in physical man, to the functions of life: the study of the nobler parts of ourselves, of those wonderful faculties which place our kind above all that have motion or life; in a word, the knowledge of moral and intellectual man belongs to the science known by the name of metaphysics, or psychology, of analysis of the understanding, but better described by that applied to it by the writers of our days, ideology. On this science, you may consult, with advantage, the philosophical works of Plato and Aristotle, among the ancients; of Bacon, Hobbes, Locke, Condillac, Bonnet, Smith, Cabanis, and Tracy, among the moderns.

CLIX. *Of sleep and waking.* The causes of excitation to which our organs are exposed during waking, tend to increase progressively their action: the pulsations of the heart, for instance, are much more frequent in the evening than in the morning, and this motion, gradually accelerated, would soon be carried to a degree of activity incompatible with the continuance of life, did not sleep daily temper this energy, and bring it down to its due measure. Fever is occasioned by long continued want of sleep, and in all acute diseases, the exacerbation comes on towards evening, the night's sleep abates again the high excitation of power: but this state of the animal economy, so salutary and so desirable in all sthenic affections, is more injurious than useful in diseases, consisting chiefly in extreme debility. Adynamy shews itself, almost always, in the morning, in putrid fevers; and petechiæ, a symptom of extreme weakness, break out during sleep. This state is, likewise, favourable to the coming on and to the progress of gangrene, and this is a pathological fact well ascertained. In all the cases I have mentioned, sleep does not improve the condition of the patients; a thing easy to conceive, since it only adds to accidental debility, the essential characteristic of the disease, weakness, which is also its principal characteristic.

Sleep, that momentary interruption in the communication of the senses with outward objects, may be defined the repose of the organs of sense, and of voluntary motion. During sleep, the inward or assimilating functions are going on: digestion, absorption, circulation, respiration, secretion, nutrition, are carried on; some as absorption and nutrition with more energy than during waking, whilst others are evidently slackened. During sleep, the pulse is slower and weaker, inspiration is less frequent, insensible perspiration, urine, and all other humours derived from the blood, are separated in smaller quantity. Absorption is, on the contrary, very active: hence the danger of falling asleep in the midst of a noxious air. It is known that the marshy effluvia, which make the Campagna di Roma so unhealthy, bring on, almost inevitably, intermittent fevers, when the night is passed there, whilst travellers, who go through without stopping, are not affected by it.

The human body is a tolerable representation of the *centripetal* and *centrifugal* powers of ancient physics. The motion of many of the systems which enter into its structure is directed from the centre to the circumference: it is a real exhalation that carries out the result of the perpetual destruction of the organs; such is the action of the heart, of the arteries, and of all the secretory glands. Other actions, on the contrary, take their direction from the circumference to the centre; and it is by their means that we are incessantly deriving from the food we take into the digestive passages, from the air which penetrates the interior of the lungs, and covers the surface of the body, the elements of its growth, and repair. These two motions, in opposite directions, continually balance each other, prevailing by turns, according to the age, the sex, the state of sleep or waking. During sleep, the motions tend from the periphery to the centre, (Hipp.) and if the organs that connect us with outward objects are in repose, the inward parts are in stronger exertion. *Somnus labor visceribus.* (*Hipp.*) A man, aged forty years, taken with a kind of imbecillity, remained about a year and a half at the Hospital of St. Louis, for the cure of some scrophulous glands: all that long time he remained constantly in bed, sleeping five sixths of the day, tortured with devouring hunger, and passing his short moments of waking in eating; his digestion was always quick and easy; he kept up his plumpness, though the muscular action was extremely languid, the pulse very weak and very slow. In this man, who to use the expression of Bordeu, lived under the dominion of the stomach, the moral affections were limited to the desire of food and of repose. Oppressed with irresistible sloth, it was never without great difficulty that he could be brought to take the slightest exercise.

Waking may be looked upon as a state of effort and of considerable expenditure of the sensitive and moving principle, by the organs of sensation and of motion. This principle would have been soon exhausted by this uninterrupted effusion, if long intervals of repose had not favoured its restoration. This interruption in the exercise of the senses and of voluntary motion, is of duration corresponding to that of their exertion. I have already said, that there are functions of such essential importance to life, that heir organs could be allowed but short moments of repose; but that these intervals are brought so close to each other, that their time is equally divided between activity and repose. The functions which keep up our connexion with outward objects, could not be without the capacity of continuing, for a certain time, in a state of equal activity: for it is easy to see how imperfect, relations interrupted at every moment, would have been; their repose, which constitutes sleep, is of equal duration.

The duration of sleep is from a fourth to a third of the day; few sleep less than six hours, or more than eight. Children, however, require longer sleep, the more, the nearer they are to the period of their birth. Old men, on the contrary, have short sleep, light, and broken: as if, says Grimaud, according to Stahl's notions, children foresaw that in the long career before them, there were time enough for performing, at leisure, all the acts of life, while old men near to their end, felt the necessity of hurrying the enjoyment of a good already about to escape.

If the sleep of a child is long, and deep, and still, it is the wonderful activity of the assimilating functions that makes it so, and perhaps the habit itself of sleep, in which he has passed the first nine months of his life, or all the time before his birth. In advanced age, the internal functions grow languid; their organs no longer engage the action of the principle of life; and the brain is moreover so crowded with ideas, that it is almost always kept awake by them. Carnivorous animals sleep longer than graminivorous, because during waking they are more in motion, and perhaps, too, because the animal substances on which they subsist, yielding them more nutritious particles, from the same bulk, they have need of less time for devouring their food and providing for their subsistence.*

Sleep is a state essentially different from death, to which some authors have erroneously likened it.† It merely suspends that portion of life, which serves to keep up with outward objects an intercourse necessary to our existence. One may say that sleep and waking call each other, and are of mutual necessity. The organs of sense and motion, weary of acting, rest; but there are many circumstances favouring this cessation of their activity. A continual excitation of the organs of sense would keep them continually awake; the removal of the material causes of our sensations tends, therefore, to plunge us into the arms of sleep: wherefore we indulge in it more voluptuously in the gloom and the stillness of night*. Our organs fall asleep one after the other; the smell, the taste, and the sight are already at rest, when the hearing and the touch still send up faint impressions. The perceptions, awhile confused, in the end disappear; the internal senses cease acting; as well as the muscles allotted to voluntary motion, whose action is entirely subject to that of the brain.

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* Probably their more powerful digestion of a more nutritious food, bringing into the system a more sudden accession of blood, oppresses them with sleep:—a sleep and a fulness of blood required to recruit the powers that have been exhausted by the laborious quest of food, and by the long continued endurance of hunger. T.

† To say that sleep is the image of death, that vegetables sleep always, is to use an inaccurate and unmeaning expression. How can plants, without brain or nerves, without organs of sense, motion, or voice sleep; when sleep is nothing but the repose of these organs?

Sleep, is a state, if not altogether passive, in which, at least, the activity of most of the organs is remarkably diminished, and that of some of them completely suspended. It is erroneously then, that some authors have viewed it as an active phenomenon, and a function of the living economy: it is only a mode or manner of being. It is to no purpose they have maintained, that to sleep required some measure of strength. Excessive fatigue hinders sleep, merely by a sense of pain in all the muscles, a pain that excites anew the action of the brain, which it keeps awake, till it is itself overpowered by sleep.

It has been attempted to shew the proximate cause of sleep. Some have said that it depends on the collapse of the laminæ of the cerebellum, which, as they conceive, are in a state of erection during waking; and they argue from the experiment in which by compressing the cerebellum of a living animal, sleep is immediately brought on. This sleep, like that produced by compression of any other part of the cerebral mass, is really a state of disease; and no more natural than apoplexy. Others, conceiving sleep, no doubt, analogous to this affection, ascribe it to the collection of humours upon the brain, during waking. This organ, say they, compressed by the blood which obstructs its vessels, falls into a state of real stupor. An opinion as unsupported as the other. As long as the humours flow in abundance towards the brain, they keep up in it an excitement which is altogether unfavourable to sleep. Do we not know, that it is enough that the brain be strongly occupied by its thoughts, or vividly affected, in any way, to repel sleep? Coffee, spirituous liquors, in small quantities, will produce sleeplessness, by exciting the force of circulation, and determining towards the brain, a more considerable afflux of blood. All, on the other hand, that may divert this fluid towards another organ, as copious bleedings, pediluvium, purges, digestion, copulation, severe cold, or whatever diminishes the force with which it is driven towards it, as inebriation, general debility, tends powerfully to promote sleep. In like manner, is it observed, that while it lasts, the cerebral mass collapses? a sign that the flow of blood into it is remarkably lessened.

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* The tissue of the eye lids is not so opake but we may distinguish through them light from darkness: accordingly a lighted torch, in the room, hinders us from sleeping. For the same reason, day succeeding to night awakens us.

The organs of the senses, laid asleep, in succession, awake in the same manner. Sounds and light produce impressions, confused at first, on the eyes and ears; in a little time, these sensations grow distinct; we smell, we taste, we judge of bodies by the touch. The organs of motion prepare for entering into action, and begin to act, at the direction of the will. The causes of waking operate by determining a greater flow of blood into the brain: they include all that can affect the senses, as the return of light and of noise with the rising of the sun; at times, they act within us. Thus, urine, fecal matter, other fluids accumulated in their reservoirs, irritate them, and send up, towards the brain, an agitation which assists in dispelling slumber. Habit too, acts upon this phenomenon, as on all those of the nervous and sensitive system, with most remarkable influence. There are many that sleep soundly amidst noises which, at first, kept them painfully awake. Whatever need he may have of longer repose, a man that has fixed the daily hour of his awaking, will awake every morning to his hour. It is as much under the controul of the will. It is enough to will it strongly, and we can awake at any hour we choose.

CLX. *Of dreams and somnambulism.* Although sleep implies the perfect repose of the organs of sensation and of motion, some of these organs persist in their activity; which obliges us to acknowledge intermediate states between sleep and waking, real mixed situations, which belong, more or less, to one or to the other. Let us suppose, for instance, that the imagination reproduces, in the brain, sensations it has formerly known, the intellect works, associates and combines ideas, often discordant, and sometimes natural, brings forth monsters, horrible, or fantastic or ridiculous; raises joy, hope, grief, surprize or terror; and all these fancies, all these emotions are recollected more or less distinctly, when we are again awake, so as to allow no doubt but that the brain has been really in action, during the repose of the organs of sense and motion. *Dreams* is the name given to these phenomena. Sometimes we speak in sleep, and this brings us a little nearer to the state of waking, since to the action of the brain is added that of the organs of speech. Finally, all the relative functions are capable of action, excepting the outward senses. The brain acts, and determines the action of the organs of motion or speech, only in consequence of former impressions; and this state, which differs from waking, only by the inaction of the senses is called *somnambulism*.

On this head we meet with surprising relations. Somnambulists have been seen to get up, dress, go out of the house, opening and shutting carefully all the doors, dig, draw water, hold rational and connected discourse, go to bed again, and awake without any recollection of what they had said and done in their sleep. This state is always very perilous. For as they proceed entirely upon former impressions, somnambulists have no warning from their senses, of the dangers they are near. Accordingly, they are often seen throwing themselves out of a window, or falling from roofs, on which they have got up, without being on that account more dexterous in balancing themselves there, as the vulgar believe, in their fondness for the marvellous.

Sometimes, one organ of sense remains open to impression, and then you can direct, at pleasure, the intellectual action. Thus, you will make him that talks in his sleep, speak on what subject you choose, and steal from him the confession of his most secret thoughts. This fact may be cited in proof of the errors of the senses, and of the need there is to correct them by one another.

The condition of the organs influences the subject of the dreams. The superabundance of the seminal fluid provokes libidinous dreams; those labouring under pituitary cachexies will dream of objects of a hue like that of their humours. The hydropic dreams of waters and fountains, whilst he who is suffering with an inflammatory affection, sees all things tinged red, that is, of the colour of blood, the predominant humour.

Difficult digestion disturbs sleep. If the stomach, over-filled with food, hinders the falling of the diaphragm, the chest dilates with difficulty, the blood, which cannot flow through the lungs, stagnates in the right cavities of the heart, and a painful sensation comes on, as if an enormous weight lay upon the chest, and were on the point of producing suffocation: we awake with a start, to escape from such urgent danger: this is what we call night-mare, an affection that may arise from other causes, hydrothorax, for instance, but which always depends on the difficult passage of blood through the lungs.

The intellectual faculties which act in dreams, may lead us to certain orders of ideas, which we have not been able to compass while awake.

Thus mathematicians have accomplished in sleep, the most complex calculations, and resolved the most difficult problems. It is easily understood, how, in the sleep of the outward senses, the sensitive centre must be given up altogether to the combination of ideas in which it must work with more energy. It is seldom that the action of imagination on the genital organs, during waking, goes the length of producing emission: nothing is more common in sleep.

The human species is not the only one, that in sleep is subject to agitations, which are generally comprehended under the name of dreams: they occur in animals, and most in those, whose nature is most irritable and sensible. Thus the dog and horse dream more than the ruminating kinds, the one barks, the other neighs in sleep. Cows that are suckling their calves, utter faint lowings: bulls and rams seem goaded by desires, which they express especially, by peculiar motions of their lips.

After what has been said of sleep and dreams, it will not be difficult to explain, why there is so little refreshment of the powers, from sleep that is harrassed by uneasy dreams. We often awake, exceedingly fatigued with the distress of imaginary dangers, and the efforts we have made to escape them.

We have seen the relations of man, with the external world, established by means of peculiar organs, which, through the intervention of nerves, all centre in one, the chief and essential seat of the function of which this chapter treats. As the phenomena of the sensations are brought about by the intervention of an unknown agent, and as like those of electricity and magnetism, they appear not to be subject to the ordinary laws of matter and motion, they have thrown open the widest field to the conjectures of ignorance, and the inventions of quackery. It is for their explanation, that the greatest abundance of theories, and the wildest, have been devised.

On the 23rd of December, it is not said in what year, a physician of Lyons, M. Petetin, was called in to a young lady of nineteen, sanguine and robust. She was cataleptic. The Doctor employed various remedies; and among others, one day bethought himself of pushing over the patient on her pillow; he himself fell with her, half stooping upon the bed, and this led him to the "discovery of the transport of the senses in the epigastrium, to the extremity of the fingers and of the toes." I use his own pompous and barbarous expressions, in announcing his discovery. Our Doctor goes on to tell with all gravity, how putting a bun on the epigastrium of the patient, she perceived the taste, which was followed by motions of deglutition: if his word is to be taken, hearing, smell, taste, sight and touch, were all there: the outward senses, being, for the time, completely laid asleep. To give an air of credibility to the matter, he adds, that she saw the inside of her body, guessed what was in the pockets of bystanders, made no mistake in the money in their purses: but the miracle was over, the moment they lapped the objects in a silk stuff, a coat of wax, or interposed any other non-conductor. Finally, to put to proof the whole power of faith in his readers, M. Petetin exclaims, "Oh prodigy beyond conception! was a thought formed in the brain without any sign of it in words, the patient was instantly acquainted with it.*" Further details of so incredible a story would be altogether superfluous.

I should not have disturbed the book of M. Petetin, from its peaceful slumber, among the innumerable pamphlets, which Mesmerism has brought into the world, if a writer on physiology had not been the dupe of this mystification, and had not proceeded from it, to write a long chapter on the metastases of sensibility.

If we should be so unfortunate as to be reproached by the lovers of the marvellous, with pushing scepticism too far, we must make answer: that M. Petetin is the sole witness of his miracle: that it is impossible, from his relation, to know when or on whom the prodigy took place; and that this zealot of magnetism might have invented this story to confound the unbelievers who ventured to turn into ridicule, his system on the electricity of the human body.

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* *Electricité animale*, 1 vol. 8vo. *Lyon*, 1808.

CHAPTER VIII.

ON MOTION.

CLXI. This Chapter will treat only of the motions performed by the muscles under the influence of the will; they are called muscles of locomotion, as it is by means of them, that the body changes its situation, moves from one spot to another, avoids or seeks surrounding objects, draws them towards itself, grasps them, or repels them. The *internal*, *involuntary*, and *organic* motions, by means of which each function is performed, have, already, been investigated separately.

The organs of motion may be distinguished into *active* and *passive*: the former are the muscles, the latter the bones, and all the parts by which they are articulated. In fact, when in consequence of an impression received by the organs of sense, we wish to approach towards the object that produced it, or to withdraw from it, the muscular organs, called into action by the brain, contract; while the bones, which obey this action, perform only a secondary part, are passive and may be looked upon as levers absolutely inert.

The muscles consist of bundles of fibres, always, to a certain degree, red in man; this colour, however, is not essential to them, since it may be removed and the muscular tissue blanched by maceration or by repeated washing.

Whatever may be the situation, the length, the breadth, the thickness, the form or the direction of a muscle, it is formed of a collection of several fasciculi of fibres, enveloped in a cellular sheath similar to that which covers the muscle itself, and separates it from the surrounding parts. Each fasciculus is formed of the union of a multitude of fibres, so delicate, that anatomy cannot reduce them to their ultimate division, and that the smallest distinguishable fibre is still formed by the juxta position of numerous fibrillæ of incalculable minuteness. As the last divisions of the muscular fibre completely elude our means of investigation, it would be very absurd to attempt to explain their minute structure, and after the example of Muys to write a voluminous work on this obscure part of physiology. Shall we say, with the above author, that each distinguishable fibre is composed of three fibrillæ progressively decreasing in size; with Leeuwenhoek, that the diameter of this elementary fibre is only the hundred thousandth part of a grain of sand; with Swammerdam, de Heyde, Cowper, Ruysch, and Borelli, that this primitive fibre consists of a series of globular, rhomboidal molecules; with Lecat, that it is nervous; with Vieussens and Willis, that it is formed by the extreme ramifications of arteries; with others, that it is cellular, tomentous, &c How is it possible to speak, with any degree of certainty, of the nature of the parts of a whole which, from its extreme minuteness, eludes our most accurate investigations. To explain the phenomena of muscular action, it is sufficient to conceive each fibre as formed of a series of molecules of a peculiar nature, united together by some unknown medium, whether that be oil, gluten, or any other substance, but whose cohesion is manifestly kept up by the vital power, since the muscles yield, after death, to efforts by which, during life, they would not have been torn; and such is their tenacity, that they are very seldom ruptured.

These fibres, which, when irritated, possess, in the highest degree, the power of shortening themselves, of contracting, however minute one may suppose them, are supplied with vessels and nerves. In fact, though they are neither vascular nor nervous, as may be readily ascertained by comparing the bulk of the vessels and nerves which enter into the structure of the muscles, with that of these organs, and by attending to the difference of their properties; each fibre receives the power of contracting, from the blood brought to it by the arteries, and from the fluid transmitted from the brain, along the nerves. A cellular sheath surrounds these fibrillæ (and the nerves and vessels perhaps terminate within it), others unite them together; the fasciculi of fibres are inclosed in common sheaths, and these unite, in the same manner, into masses varying in size, and the union of which forms the muscles; fat seldom accumulates in the cellular tissue which connects together the smallest fasciculi; it collects, in small quantity, in the interstices of the more considerable fasciculi; lastly, it is in rather greater quantity, around the muscle itself. A lymphatic and aqueous vapour fills these cells, maintains the suppleness of the tissue and promotes the action of the organ, which a fluid of more consistence would have impeded.

The greater number of muscles terminate in bodies, in general round, of a brilliant white colour, that forms a striking contras with the red colour of the muscular flesh, into which one of their extremities is imbedded, while the other extremity is attached to the bone and is lost in the periosteum, though the tendons are quite distinct from it. The tendons are formed by a collection of longitudinal and parallel fibres; their structure is more compact than that of the muscles, they are harder and apparently receive neither nerves nor vessels; they consequently possess but a very inferior degree of vitality; hence they are frequently ruptured by the action of the muscles. The muscular fibres are implanted on the surface of the tendinous cords, without being continuous with the filaments forming the latter; they join them in a different manner, and at angles more or less obtuse.

The tendons, in penetrating into the fleshy part of the muscles, expand, become thinner, and form thus the internal aponeuroses. The external aponeuroses, independent of the tendons, though the same in structure, differ from them only in the thinness and greater surface of the planes formed by their fibres. At one time, they cover a portion of the muscle to which they belong; at another, they surround the whole limb, furnishing points of insertion to the muscles; they prevent the muscles and their tendinous cords from being displaced; in a manner, direct their action and increase their power, in the same way as a moderately tight girdle adds to the power of an athlete.

We cannot admit, with Pouteau, that the muscles of the limbs though applied to the bones by aponeurotic coverings, can become displaced, so as to form herniæ. When they contract in a wrong position, some fibrillæ are torn, and this gives rise to most of those momentary and very sharp pains called cramp. I have, at present, before me, the case of a young girl, in whom the aponeurosis of the leg, exposed in consequence of an extensive ulceration, exfoliated from the middle and fore part of the limb to the instep. This exfoliation was accompanied by a displacement of the tibialis anticus and of the extensors of the toes; the leg is become deformed, the motions of extension of the foot and toes are performed with difficulty, and will soon become impossible, when the exfoliation of the tendons follows that of the aponeurosis which protected them from the air.

CLXII. When a muscle contracts, its fibres are corrugated transversely, its extremities are brought nearer to each other, then recede, and again approach towards one another. These undulatory oscillations, which are very rapid, are followed by a slighter degree of agitation; the body of the muscle, swollen and hardened in its decurtation, has acted on the tendon in which it terminates: the bone to which the latter is connected is set in motion, unless other agents, more powerful than the muscle which is in action, prevent its yielding to that impulse. Such are the phenomena exhibited by the muscles exposed in a living animal or in man, when their contractions are brought on by the application of a stimulus. But these contractions, determined by external causes, are never so strong or instantaneous, as those which are determined by the will, in a powerful and sudden manner. When an athletic man reduced by illness, powerfully contracts the biceps muscle of the arm, this muscle is seen to swell suddenly, to stiffen and to continue motionless in that state of contraction, as long as the cerebral influence, or the act of the will, which determines it, lasts.

Though the muscles manifestly swell in contracting, and though the limbs are confined by the ligatures applied round them, the whole bulk of the contractile organ diminishes; it loses in length, more than it gains in thickness. This is proved by Glisson's experiment which consists in immersing the arm in a vessel filled with a fluid, which sinks when the muscles act. We cannot, however, estimate the diminution of bulk, by the degree in which the fluid sinks, since that effect is, in part, owing to the collapse of the layers of the adipose tissue, which is compressed in the muscular interstices.

A sound state of the vessels and nerves distributed to muscles is indispensable to their contraction. If the free circulation of the blood or of the nervous fluid is prevented, by tying the arteries or nerves; if the return of the blood, along the veins, is prevented, by applying a ligature to these vessels, the muscles will be completely palsied. By dividing or tying the nerves, the action of the muscles to which they are distributed, is suddenly interrupted. The same effect may be produced by intercepting the course of the arterial blood, though in a less rapid and instantaneous manner; and it is very remarkable, that it is equally necessary that the veins should be as sound as the arteries, to enable muscular action to take place. Kaaw Boerhaave ascertained, by actual experiment, that when a ligature is applied to the vena cava, above the iliacs, paralysis of the lower extremities is brought on, as when the aorta is tied, as was done by Steno in the same situation. And this is a further proof of what we have said elsewhere, of the stupefying qualities of the blood which flows in the veins.

The irritability of the muscles destined to voluntary motions is proportioned to the size and number of the nerves and arteries which are distributed to their tissue. The tongue, which of all the contractile organs receives the greatest number of cerebral nerves, is, likewise, that which, of all those under the controul of the will, has most extent, most freedom, and most variety of motions*. The muscles of the larynx, and the intercostals, receive nearly as many, considering the smallness of these parts.

CLXIII. Of all the hypotheses applied to the explanation of the phenomena of muscular contraction, that appears to me the most ingenious and the most probable, which makes it to depend on the combinations of hydrogen, of carbon, of azote, and other combustible substances in the fleshy part of the muscle, with the oxygen conveyed with the blood by the arteries.

To effect this combination, it is necessary, not only that the muscle be supplied with arterial blood, and that oxygen come in contact with the substances which it is to oxydize, but it is required, that a stream of nervous fluid should penetrate through the tissue of the muscle, and determine the decompositions which take place, as the electrical spark gives rise to the formation of water by the combination of the two gasses of which it consists. According to this theory, first proposed by Girtanner, all the changes which take place, during the contraction of a muscle, the turgescence, the decurtation and the induration of its tissue, its change of temperature depend on this reciprocal action of the elements of the muscular fibre, and of the oxygen of arterial blood.

Muscular flesh is harder, firmer, and more oxydized, according as the animal takes much exercise. We well know, what a difference there is, between the flesh of wild and of the domestic animals; between the flesh of our common fowl and that of birds accustomed to remain long on the wing; in the former, it is white, tender and delicate, while, in the latter, it is tough, stringy, dark-coloured, carbonaceous, and of a very strong smell. Respiration, of which the principal use is to impregnate arterial blood with the oxygen necessary to the contractions of the muscular fibre, is more complete, decomposes the greater quantity of atmospherical air, in those animals that are naturally destined to most exertion. Those birds which support themselves in the air by powerful and frequent motions, have, likewise, the most active respiration. Athletes, who astonish us by the developement of their muscular organs, and by the powerful efforts of which they are capable, all have a very ample chest, a powerful voice, and very capacious lungs*. In running, as there is a considerable consumption of the principle of motion, we pant, that is, we breathe in a hurried manner, that there may be the greatest possible quantity of blood oxydized to perform the contractions necessary to the exercise of running.

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* It is scarcely necessary to repeat, that I am not speaking of those motions, more or less involuntary, performed by muscles which receive their nerves, in part or wholly, from the great sympathetics. Though the particular nature of these nerves has a remarkable influence on the organs to which they are distributed, we find, that the general rule is almost without exceptions, for the heart and diaphragm, which hold the first rank among the parts endowed with irritability, receive a considerable number of vessels and nerves.

CLXIV. *Of the preponderance of the flexors over the extensors*†. The extensor muscles are, generally, weaker than the flexors; hence the most natural position, that in which all the powers are naturally in equilibrio, that which our limbs assume during sleep, when the will ceases to determine the vital influx to the parts under its controul, that in which we can continue longest without fatigue, is a medium between flexion and extension, a real state of semi-flexion.

Attempts have been made to discover the cause of this preponderance of the flexor muscles over their antagonists. According to Borelli, the flexors being shorter than the extensors of the same articulation, and contracting equally‡, the former must occasion a more extensive motion of the limbs, and determine them towards a state of flexion. But it is, in the first place, incorrect to say, that the flexors are shorter than the extensors; and, in the next place, if we are ta estimate, by the length of a muscle, the extent of motion that may be prodnced by its action, we ought not to measure the whole of the fleshy part, nor to include in the calculation, the tendinous cord which terminates it, but to consider the length of its fibres, on which depends entirely the extent of motion produced by its contractions.

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* I never saw a very strong man that had not broad shoulders, which indicates a considerable developement of the cavity of respiration. If there be individuals that seem to be exceptions to this general law, it is that by frequent exercise, and by a laborious life, they have increased the natural power of their muscles. This increase is seldom universal, but almost always limited to certain parts which have been most employed; as the arms, the legs, or the shoulders.

† The theory of the preponderance of the flexors is intirely my own and was first proposed by me, in the collection of memoirs of the Medical Society of Paris, for the year VII. of the Republic (1799).

‡ Musculi flexores ejusdem articuli breviores sunt extensoribus, et utrique æquè contrahuntur Prop. 130, de motu animalium.

The degree of decurtation of which a muscle is capable, is always proportioned to the length of its fleshy fibres, as is the power of contraction to the number of the fibres. Now, if the fibres of the flexors are in greater number than those of the extensors, it follows as a necessary consequence, that the limbs will be brought into a state of flexion, when the principle of motion shall be distributed to them in an equal quantity; and even though the number of fibres should be the same in the flexors and extensors, the limbs would still be in a state of flexion, if the fibres of the former being longer, they made the parts move through a greater space.

If we examine the different parts of the body, the articulations of the limbs and especially of the knee, the knowledge of which is of the highest importance in understanding the theory of standing, it will be seen that the flexor muscles exceed the extensors, in the number and length of their fleshy fibres. If we compare the biceps cruris, the semi tendinosus, the semi membranosus, the rectus internus, the sartorius, the gemelli, the plantaris and the popliteus, which all concur in the flexion of the leg, to the triceps cruris and to the rectus, which extend the leg, we shall readily understand that the fibres of these last are much shorter, and in smaller number. Those of the sartorius and rectus internus are the longest of all the muscles employed in voluntary motion; the fibres of the posterior muscles of the limb are not inferior in length to the fibres of the muscles at the fore part.

Besides, the flexor muscles are inserted into the bones which they are to move, farther from their centre of motion. In fact, if the insertion of the semi membranosus is situated nearly at the same height, the sartorius the rectus internus, the semi tendinosus, the biceps and the popliteus are inserted lower than the extensors of the leg. But this difference is particularly observable in the plantaris and gemelli, which terminate at the greatest possible distance from the centre of motion, and which act with a very long lever*: lastly, most of these muscles depart much more than the extensors, from a parallel direction to the bones of the leg. We all know the curved line of the course of the sartorius, of the rectus internus and semi tendinosus, by which the angle of their insertion becomes more favourable.

The flexor muscles which, on their being first called into action, are nearly parallel to the levers which they are to move, tend to become perpendicular to them, in proportion as the motion of flexion is carried on. Thus, the brachialis, the biceps brachii, and the supinator longus, the mean line of direction of which is nearly parallel to that of the bones of the fore arm, when the flexion of this limb commences, become oblique, then perpendicular to this bone, and at last form with it the angle most favourable to their action. The same applies to the flexors of the leg; the angle of their insertion becomes greater, the more it bends on the thigh. The extensors, on the contrary, are in the most favourable state for action, at the moment when their contraction begins, in proportion as the extension goes on, they have a tendency to become parallel to the levers which they set in motion; their action even ceases before the parallelism is complete, at the elbow by the resistance of the olecranon, and at the knee, by the numerous ligaments and by the tendons situated towards the posterior part of the articulation.

The flexor muscles have, therefore, fibres of greater length and more numerous than those of the extensors. They are inserted into the bones, at a greater distance from the centre of their motion, at an angle less acute and which increases in size, as the limbs bend. The union of these causes gives to the limbs their superior power, and the greater range of motion in these muscles, is a consequence of the arrangement of the articulating surfaces, which almost all incline towards the side of flexion.

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* We may, in this respect, compare the gemelli to the supinator longus, the use of which is not limited, as was shewn by Heister, to the supination of the hand, but which is, likewise, a flexor of the fore arm, and acts the more powerfully, as its inferior insertion is at a greater distance from the elbow joint, and as its fibres are the longest of all those of the muscles of the upper extremity.

This preponderance of the flexor muscles, varies according to the different periods of life; in the fœtus, the parts are all bent very considerably; this convolution of the young animal may be perceived from the earliest period of gestation, when the embryo, of the size of a French bean, and suspended by the umbilical cord, floats in the midst of the liquor amnii, in a cavity in which it is more and more confined, as it approaches to the period of its birth. This excessive flexion of the parts, which was required to enable the produce of conception to accommodate itself to the elliptical shape of the uterus, concurs in giving to the muscles which produce it, the superiority which they retain during the remainder of life. The new-born child preserves, in a very remarkable manner, the habits of gestation; but, in proportion as it grows, it straightens its body, and, by frequent attempts to stretch itself, shews that a just proportion is about to take place, between the muscular powers. When the child becomes capable of standing erect, abandoned to its own powers, all its parts are in a state of semi flexion, it staggers and is unsteady on its feet. Towards the middle of life, the preponderance of the flexors over the extensors becomes less apparent; a man enjoys fully and completely his power of locomotion; but, as he advances in years, this power forsakes him; the extensor muscles gradually return to the state of comparative debility of infancy, and become incapable of supporting the body, in a fixed and permanent manner.

CLXV. The state of our limbs, during sleep, approaches to that of the fœtus, which according to Buffon, may be considered to be in a profound slumber. The cessation of sleep is attended in man, as well as in most animals, by frequent stretchings. We extend our limbs forcibly, to give to the extensors, the tone which they require during the state of waking*. Barthez accounts, in the same way, for the manner in which the cock announces his waking, by crowing and flapping his wings.

It may happen, in consequence of a morbid determination of the vital principle, that our limbs may remain in a state of extension during sleep. Hence Hippocrates recommends, that the state of the limbs be carefully attended to, while the patient sleeps, for, as he observes, the further that condition is from the natural state, the greater the danger to be apprehended of the patient's life. In certain nervous diseases characterized by a manifest aberration in the distribution of the vital power, a continued state of extension must be considered a symptom highly dangerous; I have had several times occasion to observe, that in cases of wounds attended with convulsions and tetanus, these alarming affections were announced by the permanent extension of the limbs during sleep, before a difficulty of moving the jaw could give rise to any apprehension of their approach.

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* Haller thinks that these extensions are intended to relieve the uneasy sensations occasioned by a long continued flexion. *Nunc quidem homines and animalia extendunt artus, qúod iis ferè conflexis dormiant, et ex eo perpetuo situ, in musculis sensus incommodus oriatur, quem extensione tollunt.* (*phænomena expergiscentium, Elementa physiologiæ*, tom. V. p. 621.

Disease and excesses of all kinds, occasion in the extensor muscles a relative weakness that is very remarkable, hence we see convalescents, and those who have been addicted to voluptuousness, walk with bending knees, the more so as their debility is greater and as the force of the extensors is more completely exhausted. The flexion of the knees is then limited by that condition in which the tendons of the extensors of the leg act on the tibia, at an angle sufficiently great to make up for their diminished energy. There exists a condition of the animal economy, in which all the muscular organs appear wearied with exertion, and the limbs assume indifferently any position. In this state, which is always a very serious one, as it indicates an almost complete want of action in a system of organs whose functions are absolutely essential to life, a state to which physicians have given the name of *prostration**, the limbs if unsupported, fall of their own weight, as if they were palsied; the trunk is motionless and supine.—The patient is incapable of changing his attitude, and yielding to the weight of his body, sinks on the inclined plane formed by the bed, and seems very heavy to those who may attempt to raise him, because from his helplessness, he requires to be moved as an inert substance.

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* It is from a knowledge of the strength of his patient, that the physician, in the treatment of disease, deduces the most instructive indications. It seems to me, that we ought to endeavour to characterize by specific terms, the different states of animal adynamia in different diseases. Our language, less fruitful in imagery than the ancient languages, will not easily furnish these characteristic denominations, so useful in a science which should paint objects in their truest colours, in terms most approaching to nature. It will, therefore, be necessary to have recourse to the Greek and Latin languages, and perhaps to give the preference to the latter, which is generally understood by those who practise the art of healing. The application of this principle, to the different

CLXVI. *Of the power of the muscles, of the mode of estimating that power.* The actual power of the muscles is immensely great, seems to grow, in proportion to the resistance which it meets with, and can never be estimated with precision. Borelli was guilty of a serious mistake, in estimating the force of a muscle by its weight, compared to that of another muscle, for, muscles, may contain cellular tissue, fat, tendinous parts, and aponeuroses, without being the more powerful. Their strength is always proportioned to the number of their fleshy fibres; hence, Nature has multiplied those fibres in the muscles which are intended for powerful action. And in order that this great number of muscular fibres might not add too much to the bulk of the limbs, they are made shorter, by bringing near to each other their insertions, which occupy extensive sufaces, whether aponeurotic or osseous. We may, in general, judge of the power of a muscle, by the extent of the surfaces to which its fleshy fibres are attached; thus, the gemelli and the soleus have short compressed fibres, and lying obliquely between two large aponeuroses.

If the force with which a muscle contracts, is proportioned to the number of its fibres, the degree of decurtation of which it is capable, and consequently, the range of motions which it can communicate to the limbs, are proportioned to the length of the same fibres. Thus, the sartorius whose fibres are longer than any in the human body, is also capable of most contraction, and performs the most considerable motions of the leg. It is impossible to fix any precise limits to the decurtation of every particular muscular fibre; for, if the greater part of the long muscles of limbs lose little more than a third of their length, in contracting, the

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kinds of fever will prove its utility, and will, doubtless, be an inducement to extend it to all the classes of morbid derangements.

In febre inflammatoriâ seu synocho simplici (angeiotenicâ)	*Oppressio virium.*
In febre biliosâ seu ardente (meningo-gastricâ)	*Fractura virium.*
In febre pituitosâ, seu morbo mucoso (adenomeningeâ)	*Languor virium.*
In febre putridâ (adynamica)	*Prostratio virium.*
In febribus malignis seu atactis	*Ataxia virium.*
In febre pestilentiali (adeno-nervosâ)	*Sideratio virium.*

The first term which is easily turned into French, expresses, with much precision, that condition in which the living system, far from being deficient in circular fibres of the stomach which, in its greatest dilatation, form circles nearly a foot in diameter, may contract, to such a degree, when this organ has been long empty, as to form rings of scarcely an inch in circumference. In cases of extreme elongation or constriction, does the change that takes place, affect the molecules that form the muscular fibre, or the substances which connect them together, or does it affect, at once, both the fibre and the parts by which these fibres are united together?

However great the power of the muscles may be, a great part of this power is lost, from the unfavourable disposition of our organs of motion; the muscular powers, almost always, parallel to the bones which they are to move, act with the more disadvantage on these levers, as the mean line of their direction is further from the perpendicular, and is nearly parallel to them.

The greater part of muscles are, besides, inserted in the bones, very near their articulations or the centre of motion, and move them as levers of the third kind, that is, are always placed between the fulcrum and the resistance; by multiplying thus, in the animal machine, the levers of the third kind, Nature has lost in power, but has gained in strength, for, in this kind of lever, the power moves through a very small space, but makes the resistance move through a very considerable one. Besides, the fleshy fibres, in shortening themselves, do not act directly on the tendon in which the muscle terminates, these fibres generally join, in an oblique direction, the aponeurotic expansion formed by the tendinous cord, as it penetrates into the muscular mass; now their action being exerted in a direction more or less oblique, is decomposed and none is advantageously employed, but that which takes place in the direction of the tendon. The muscles frequently pass over several articulations, in their way to the bone which they are to

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strength, is encumbered by its excess and is oppressed by its own powers. It might, with slight modifications, be applied to all the kinds of phlegmasias and active hemorrhages.

The second denomination, not so easily translated, expresses the sense of general contusion and bruise, of patients labouring under bilious fever (*meningo-gastrica*) complain all over their limbs.

This sensation is, likewise, it is true, experienced in pituitary fever, but this is more particularly characterized by languor and loss of strength. The same is to be observed in many patients of a phlegmatic temperament.

The prostration, which is so remarkable a character of putrid fevers, and in consequence of which they are called adynamic, is easily recognized by the move; a part of their power is lost, in the different degrees of motion on each other, of the parts on which the bone rests into which the muscles are inserted. All these organic imperfections are attended with an enormous misapplication of power and with a waste of the greater part of it. It has been reckoned, that the deltoid muscle employs a power equal to 2568 pounds to overcome a resistance of 50. We are not to imagine, however, that there is a loss of 2518 pounds; for the deltoid muscle acting both on the shoulder and on the arm, about one half of its power is employed on each of these parts; hence it is said, that in estimating the whole power of a muscle, one should double the effect produced by its contraction, its action being applied, at the same time, both on the weight which it raises, or on the resistance which it overcomes, and on the fixed point to which its other extremity is inserted.

If the muscles were quite parallel to the bones, they would be incapable of moving them, in any direction. On this account, Nature has, as much as possible, corrected the parallelism, by removing, as we shall see, in speaking of the osseous system, the tendons from the middle line of direction of the bones, and by augmenting the angles at which they are inserted into them, either by placing, along their course, bones which alter their direction, as the patella and the sesamoid bones; by increasing the size of the articular extremities of the bones, or by pullies, over which the tendons or the muscles themselves are reflected, more or less completely, as is the case with the circumflexus palati and the obturator internus.

Nature has not, therefore, neglected mechanical advantages as much as one might be led to imagine, on a slight examination of the organs of motion. And if it be considered, that in the different conditions of life, we do not require strength so much as rapidity

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total cessation, or by an impaired condition of all the functions performed by muscular organs, as voluntary motion, respiration, circulation, digestion, the excretion of urine, &c.

The disordered condition of the vital powers characterizes the ataxiæ; there is considerable irregularity in these fevers, with a very anomalous course of symptoms. In this point of view, one might compare it to several kinds f nervous disorders.

Lastly, the word syderation appears to me to express, very forcibly, that sudden and deep stupor which overwhelms patients seized with the plague of the East.

of motion, that the power might be gained by increasing the number of fibres, while it was impossible to obtain velocity, by any other means than by employing a particular kind of lever, and that, in short, to give our limbs the most advantageous form, it was necessary that the muscles should be applied to the bones, it will be confessed, that in the arrangement of these organs, Nature, in frequently sacrificing power to quickness of motion, has conciliated, as much as possible, these two almost irreconcileable elements.

Though the lever of the third kind is that most frequently employed in the animal economy, the two other kinds of lever are not altogether excluded from it; there are even limbs which represent different levers, according to the muscles which set them in motion; thus, if we take the foot as an instance, it will present us with levers of every kind. The foot, when raised from the ground and held up and raised towards the leg, forms a lever of the first kind; the fulcrum is in the articulation and separates the power, which is at the heel, from the resistance which is at the tip of the foot that points downwards; if this end of the foot rest on the ground, and if we stand on tip-toe, they are changed into levers of the second kind; the power continues at the heel, but the fulcrum is removed to the other extremity of the lever, and the resistance to the middle; and this resistance is very considerable, since the whole weight of the body rests on the articulation of the foot with the leg. In standing on tip-toe, the muscles of the calf of the leg become prodigiously fatigued, though their action is assisted by the most favourable lever*, adapted to the greatest resistance which nature can oppose to herself. Lastly, the foot moves as a lever of the third kind, when we bend it on the leg.

CLXVII. What is called the fixed point, in the action of muscular organs, does not always deserve that name. Thus, though it may be said, very correctly, that the greater part of the muscles of the thigh have their fixed point in the bones of the pelvis, to which their upper extremity is attached, and though they move the femur on the ilia which are less moveable; when the thigh is fixed by the action of other muscles, these move the pelvis on the thigh, and that which was the fixed point, becomes moveable. The same applies to the other muscles of the body, so that the fixed point is merely that which, generally, is a fulcrum to the muscular action. This necessary fixed state of one of the bones, to which is attached one of the extremities of a muscle which we wish to contract, renders it necessary, in performing the slightest motion, that several muscles should be called into action, which implies a very complicated mechanism. Nothing is easier to prove. Suppose a man stretched on the ground or lying on his back; if he wish to raise his head, it will be necessary that his chest become the fixed point of action of the sterno cleido mastoidei, whose office it is to perform this motion. Now, in order that the pieces forming this osseous structure may remain motionless, it will be required, that the chest should be fixed by the action of the abdominal muscles which, on the other hand, have their fixed point in the pelvis that is itself fixed in its place, by the contraction of the glutæi muscles. It was on this principle that Winslow first suggested, that in reducing a hernia, the patient should be laid in an horizontal posture, with injunctions not to raise his head, that the abdominal muscles being relaxed, their different openings might yield more easily to the reduction of the parts.

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* Of levers with arms of unequal length, that of the second kind is the most favourable, since the arm of the power is uniformly longer than that of the resistance.

In case the two opposite points to which the extremities of a muscle are attached, are equally moveable, they approach towards each other, during the contraction of the muscle, by making them move through equal spaces. These spaces would not be equal, if the mobility were different. Each muscle has its antagonist, that is, another muscle whose action is directly opposed to it. Thus, the flexors balance the action of the extensors, the adductors perform motions different from those of the abductors. When two antagonizing muscles of equal power act, at the same time, on a part equally moveable, in every direction, the opposite powers neutralize each other, and the part remains motionless. If there is a difference in the degree of contraction, the part is directed towards the muscle whose contraction is the most powerful: if the opposition is not direct, the part follows a middle direction, between the two powers which move it. Thus, the rectus externus muscle of the eye is not antagonized by the rectus inferior; hence when these two muscles come to contract, at the same time, the eye is not carried downward or outward, but at once downward, and outward; it is then said to move in the diagonal of a parallelogram of which the sides are represented by the muscles in action.

CLXVIII. *Of the nature of muscular flesh.* I shall not speak, at present, of the manner in which the muscles receive nourishment, by retaining within the meshes of their tissue, the fibrina which the blood conveys to them in such quantity, that several among the ancients and moderns have called the blood, "liquid flesh; an expression at once forcible and correct, since all the organs are repaired and grow, by the solidification of its different parts. Haller first observed that most of the muscular arteries were very tortuous in their course to the muscles. This disposition which cannot fail to slacken, very considerably, the course of the blood, favours the formation and the secretion of the fibrous element which the muscles appropriate to their own substance, and to which it bears so strong an affinity. Motion influences, in a very remarkable manner, this nutritive secretion. The muscles that are most in action, uniformly acquire the greatest size and strength; if left in a state of complete inaction, they become exceedingly reduced in size, from the suspended secretion of the fibrinous principle. Muscular motion promotes, very remarkably, the circulation and the distribution of all the fluids. The flow of venous blood, after bleeding, is never copious, unless the muscles of the fore arm are made to contract, by making the patient hold the lancet case, and desiring him to move it round in his hand.

The chemical nature of the muscular fibre is nearly the same as that of the fibrina obtained from the blood*. Like the latter, it contains a great quantity of azote, and is, consequently, very much animalized and exceedingly putrescent. It is from muscular flesh, that M. Berthollet obtained, in considerable quantity, the peculiar animal acid, called by that chemist, the *zoonic acid.* Lastly, the element of the blood, by means of which the muscular flesh is repaired, fibrina, is already imbued with vital properties, even while it yet flows in a state of combination with the other parts of the fluid. This fibrina, extracted from the blood and subjected to the galvanic influence, is distinctly seen to quiver and contract under that influence. At what period does this substance acquire the power of contracting? It is, doubtless, at the moment when it becomes organized, in passing from the liquid to the solid state. What relation does there exist, between the organization of matter and the vital properties with which it is endowed? This question cannot be answered, in the present state of our physiological knowledge.

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* Nothing can prove, in a more complete manner, the essential difference between the fleshy parts of muscles and their tendinous and aponeurotic parts, than the chemical analysis of these organs. The tendons and aponeuroses may be completely resolved into gelatine, by long boiling, which, on the contrary, parches the muscular flesh, by exposing the fibrina, in consequence of the melting of the fat, of the cellular tissue, and of the albuminous juices in which it is enveloped.

CLXIX. A Professor of Anatomy in the University of Bologna, Galvani, was one day making experiments on electricity. In the laboratory, not far from the machine, lay some skinned frogs, of which the limbs were convulsed every time a spark was taken. Galvani, struck with the phenomenon, made it a subject of inquiry, and found that metals, applied to the nerves and to the muscles of these animals, determined quick and strong contractions, when they were disposed in a certain manner. He gave the name of Animal Electricity to this set of new phenomena, from the analogy he thought he perceived between its effects and those of electricity. The discovery was made public: many scientific men, chiefly those of Italy, and Volta among others, were eager to make additions to the labours of the inventor. The medical Society of Edinburgh thought it right to take this point of physiology as the subject of one of its annual prizes, which was adjudged to the work of Professor Crève of Mentz, in which the term metallic irritation *(irritamentum metallorum)* is substituted to that of animal electricity. This new expression is essentially bad, since it implies that irritation by metals can alone determine the galvanic phenomena, when charcoal, water, and many other substances produce them as well. The term of animal electricity has been also laid aside, notwithstanding the great analogy between the effects of electricity and those of galvanism, and this last name has been preferred, which applying equally to the whole of the phenomena, immortalizes the name of the first observer.

To produce the galvanic phenomena, it is necessary to establish a communication between two points of a series of nervous and muscular organs. In this way, there is formed a circle of which one arc is composed of the animal parts that are subjected to the experiment; while the other arc is represented by the instruments of excitation, which consist commonly of several pieces, some of them placed under the animal parts, and called supports, and the others, by which the communication with these is established, called *communicators*.

To form a complete galvanic circle, take the thigh of a frog stripped of its skin, detach the crural nerve down to the knee, and apply it on a plate of zinc; let the muscles of the leg lie on a plate of silver, then complete the arc of excitation and the galvanic circle, by establishing a communication between the two supports with an iron wire, or copper, tin, or lead: at the moment of touching the two supports with the conductor, a part of the animal arc formed by the muscles of the leg, will be convulsed. Although this arrangement of the animal parts, and of the galvanic instruments is the one most favourable to the production of these phenomena, there is room for varying a good deal the composition of the animal arc and the arc of excitation. Thus, you obtain contractions, by placing the two supports under the nerve, and leaving the muscles without the galvanic circle; which proves, that the nerves essentially constitute the animal arc. To conclude, the galvanic circle may be entirely animal: for this purpose take a very lively frog, that is to say, one enjoying strong contractility: after insulating the lumbar nerves, present these nerves to the thigh of the frog; at the moment of contact, the limb will be convulsed. Professor Aldini is the first author of this experiment, which is really one of the most curious, as it leads more directly to the explanation of the influence of nerves on muscular organs.

There is no need that the nerves be untouched to allow the contractions, they are observed, when these organs are tied, or cut, provided there be simple contiguity between the two ends made by the section. This shews that no rigorous conclusion must be drawn from what happens in galvanic phenomena, to what takes place in muscular action, since it is enough that a nerve in man be cut or compressed by a ligature, to take from the muscles to which it is sent, the faculty of moving. I have, however, observed that disorganizing, by a strong contusion, the nerve which forms the whole or merely a part of the animal arc, interrupts, or at least greatly impedes the galvanic current.

The epidermis obstructs galvanic action: which always is faint in parts so covered. When it is moist, thin, and delicate, the interruption is not complete, and hence the possibility is inferred of making on one self the following experiments:—

Lay upon the tongue a plate of silver, and a plate of zinc beneath; let their edges touch, and you will feel a sharp taste with a slight quivering. Apply upon the eyes two pieces of different metals: make them communicate and you will perceive sparks. Put a piece of silver in your mouth; and a piece of tin into your anus, or copper or any other metal: connect them with an iron wire: the long hollow muscle which, reaching from the mouth to the anus forms the base of the digestive canal, feels a considerable shock: this has been carried the length of exciting a gentle purging, accompanied with slight cholic. Humboldt, after detaching the epidermis from the nape of the neck and the back, by two blisters, had metals applied to the parts laid bare, and felt in each sharp prickings, accompanied with a sero-sanguineous excretion, at the moment of communication.

You may construct the arc of excitation with three kinds of metal, or two, or even one; with alloys, amalgams, or other metallic and mineral combinations; with carbonaceous substances*, &c. and it is observed, that metals which are, in general, the most powerful exciters, provoke contractions with the greater success the larger surface they present. The metals have more or less power of excitation: thus it is found that zinc, gold, silver, and tin, hold the first rank, then copper, lead, nickel, antimony, &c. without any apparent relation between their different degrees of exciting power and their physical properties, as their weight, malleability, &c.

CLXX. Galvanic susceptibility is like muscular irritability: it is exhausted by too long exertion; and returns when the parts are left for a time in repose. Dipping the nerves and muscles in alcohol or opiate solutions, weakens and even will extinguish this susceptibility, in the same manner, no doubt, as in the living man, the immoderate use of the same substances, benumbs and paralyzes the muscular action. Immersion in oxygenated muriatic acid restores to the exhausted parts the power of being affected by the stimulus. Humboldt has observed that the season of spring, as well as the youth of the frog, was favourable to the production of the phenomena, and that the fore-feet of these creatures with which the male fixes himself on the back of the female, by pressing her sides, are more excitable than the hind feet; whilst in the other sex, it is the hind feet that are the most susceptible. M. Hallé ascertained, by experiments made at the School of Medecine in Paris, that the muscles of animals killed by repeated shocks of an electrical battery, receive an increase of galvanic susceptibility; that this property subsists, without alteration, in animals dead of asphyxia or killed by immersion in mercury, pure hydrogen gas, carbonated hydrogen, oxygenated muriatic acid, and sulphureous acid gasses, by strangulation, by privation of air in an exhausted receiver; that it is weakened after suffocation by drowning, by sulphureted hydrogen, azote, and ammoniacal gas, and absolutely destroyed by suffocation in the vapour of charcoal. Spring is the season in which galvanic experiments succeed best, an excess of life seems, at that time, to animate all beings: it is accordingly at this epoch, that the greater part of them are employed in the reproduction of their kind.

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* I employed successfully, in the winter of the year VIII, pieces of ice both as supports, and as communicators.

CLXXI. Galvanic susceptibility disappears in the muscles of warm-blooded animals, as the vital warmth goes off. Sometimes even, when their life has ended in convulsions, their contractility is gone, though there be still warmth, as if this vital property were exhausted by the convulsions of death. In the cold-blooded, susceptibility is more permanent: long after separation from the body, and even to the moment when putrefaction begins, the thighs of frogs are affected by galvanic excitation; no doubt, because, in these animals, irritability is less intimately connected with respiration, because life is less one, is more divided among different organs which have less need of action on each other to produce its phenomena.

Contractility is then, as I have shewn in another work, too fleeting in the human body, to enable us to derive from galvanic experiments on it, after death, any light on the greater or less weakening of this vital property in different diseases. Those authors who have maintained that galvanic susceptibility is sooner extinct on the bodies of those that die of scorbutic affections, than of those that die of inflammatory diseases, have suggested a probable conjecture, which cannot, however, be established on experiment.

Dr. Pfaff, Professor in the University of Kiel, who, next to Humboldt, is of all the scientific men of Germany he who has attended most successfully to experiments on galvanism, has had the goodness to communicate to me the following facts:

The galvanic chain produces sensible actions, that is to say, contractions, only at the moment in which it is completed, by establishing a communication among its parts. After it is made, that is, during the time that the communication remains, all appears tranquil; yet the galvanic action is not suspended. In fact, excitability appears singularly increased or diminished in the muscles that have been left long in the galvanic chain, according to the variations of the reciprocal situation of the associated metals. If the silver have been applied to the nerves and the zinc to the muscles, the irritability of these is increased in proportion to the time they have remained in the chain. By this means, you may revivify, in some sort, frogs' thighs, which will afterwards obey an influence that was no longer sufficient to excite them. By allotting the metals differently, applying the zinc to the nerves, and the silver to the muscles, the opposite effect takes place, the muscles which were introduced into the chain with the liveliest irritability, seem entirely paralyzed, if they have remained long in that situation.

This difference depends, very evidently, on the direction of the galvanic fluid, determined towards the nerves or towards the muscles, according to the arrangment of the metals. It is of importance to be known for the application of galvanism to the treatment of disease. Where the object is to revive enfeebled irritability, it is better to employ the tranquil and permanent influence of the closed galvanic chain, by distributing the silver and zinc, so that the silver shall be nearest to the origin of the nerves, and the zinc upon the muscles of which it is wished to re-excite the torpid or suspended action, than to employ that sudden influence, which, in an instant, excites and is gone. Professor Pfaff told me, he had treated successfully a hemiplegia, by placing silver within the mouth, and a plate of zinc on the paralyzed arm; at the end of 24 hours of uninterrupted communication, the limb could already exert some slight motions. To diminish, on the other hand, the irritable energy in many spasmodic affections, you must invert the applications of the metals, place the zinc as near as possible to the the central extremity of the nerves, and the silver on their superficial terminations.

CLXXII. *Apparatus of Volta, or galvanic pile.* Curious to ascertain the relation apprehended by several Natural Philosophers, between electricity and galvanism, M. Volta invented the following apparatus, which is described, as well as the effects it produces, in a memoir presented by him to the Royal Society of

London. These effects shew the most striking analogy between these two orders of phenomena, as will be seen by a succint view of them. Raise a pile, by laying successively, one above another, a plate of zinc, a piece of moistened paste board, a plate of silver; then a second plate of zinc, &c. till the pile is several feet high: for, the effects are stronger the higher it is: then, touch, at once, the two extremities of the pile with the same iron wire: at the instant of contact, a spark is seen at the extremities of the pile, and often, at the same time, luminous points, at different heights, in places where the zinc and silver touch. Tried by the electrometer of M. Coulomb, the extremity of the pile, which answers to the zinc, appears positively electrified; that which is formed by the silver, gives, on the contrary, indications of negative electricity.

If after wetting both hands, by dipping them in water, or still better, in a saline solution, you touch the two extremities of the pile, you feel, in the joints of the fingers and elbow, a shock followed by an unpleasant pricking.

This effect may be felt by several persons holding hands, as in the Leyden experiment; it is the more sensible, the composition of the chain being in other respects the same, as the chain consists of fewer people, and as they are better insulated.

Notwithstanding this great resemblance of the effects of galvanism to those of electricity, it differs from it essentially in this, that the voltaic pile is constantly electrifying itself spontaneously, that its effects seem increased, the more they are excited, and are speedily renewed in greater strength, whilst the Leyden phial, once discharged, requires to be electrified anew. This loses, moreover, by damp, its electrical properties, whilst those of the pile remain the same, though water is running on all sides, and are quenched only by entire immersion in that fluid.

If you introduce into a tube filled with water, and hermetically closed with two corks, the extremities of two wires of the same metal, which, at the other extremity are in contact, one with the summit and one with the base of the galvanic pile, these two ends when brought within the distance of a few lines, undergo manifest changes, at the moment of touching the extremities of the pile. The wire in contact with the extremity which answers to the zinc, becomes covered with bubbles of hydrogen gas; that which touches the extremity formed by the silver, becomes oxydized. If the ends of the wire dipping into the water, are brought into contact, all effect ceases: there is no disengaging of bubbles on one side, no oxydizement on the other. The plates of zinc and silver become alike oxydized in the pile, but only on the surfaces which touch the moistened pasteboard, and very little, or not at all, on the opposite surfaces, &c.

Facts so singular could not but awaken the attention of all natural philosophers. Accordingly, there was great eagerness, every where, to repeat and verify these first experiments, to vary and to extend them, and to rectify the errors into which their authors might have fallen. Lastly, it has been attempted to explain the manner in which the apparatus acts in the production of hydrogen gas and in oxydizement.

M. Fourcroy ascribes this phenomenon to the decomposition of water by the galvanic fluid, which abandons the oxygen to the wire that touches the positive extremity of the apparatus, then conducts the other gas, in an invisible manner, to the extremity of the other wire, where it allows it to escape: and this opinion, supported by many experiments detailed in a Mémoir presented to the National Institute, is the most probable of all that have hitherto been suggested.

The galvanic pile has been employed, with effect, to produce with more energy, muscular contraction. If you place in the mouth of an animal, fresh killed, a conductor attached to one of the poles or extremities of the pile, and insert into the rectum, the conductor connected with the other extremity, you observe contractions so strong, that the whole body of the animal quivers and is agitated, the eyes roll in their sockets, the jaws strike against each other, and the tongue is thrust out. The same effects take place after decapitation of the animal. These experiments have been repeated on the bodies of persons executed by the guillotine: by applying to the neck, the head that had been separated from it, and applying to both, conductors connected with the pile, effects have been produced, which seemed at first miraculous. There are few muscles that retain, longer than the diaphragm, their sensibility to the galvanic action; in the heart, and the intestines it is the same. I know not why the internal muscles have been held by many authors to be insensible to this kind of excitation. I have seen them constantly obey it, and many experiments made publicly in my lectures, have always afforded me this result.

CLXXIII. In the first edition of this work the article galvanism ended here. Since its publication, there has been an accession of new facts to those already known. Volta came to Paris: he gave an exposition of his doctrine, in several memoirs read before the National Institute of France, and he repeated before a committee, the principal experiments on which it is founded. They have appeared so conclusive, that the theory of this illustrious philosopher has been unanimously adopted, and at this day, all men of science admit the entire identity of the phenomena of galvanism, and those of electricity. Certain bodies, therefore, in nature, and especially metals, possesses the property of electrifying themselves, that is to say, of producing the greater part of the phenomena which denote the accumulation of electricity in a body, such as shocks, sparks, irritations, &c. merely by contact.

It may be thought that galvanism, being only a new form of electrical action, ought to be confined to books of natural philosophy: and in fact, in the present state of things, it belongs rather to the physico-chemical sciences, than to those of the animal economy. However, the galvano-electric irritation produces on our organs, effects more decided than the ordinary effects of electricity. It seems to have more intimate relations with them: accordingly, it has been endeavoured to bring it into use in the treatment of disease. The experiments made by M. M. Halle and Thillaye, prove that the effects of the pile penetrate, and affect the nervous and muscular organs, more deeply than the common electrical apparatus; that they provoke lively contractions, strong sensations of pricking and burning, in parts which disease renders insensible to electrical sparks, or even shocks. A man whose muscles of the left side of his face were all paralysed, found no effect from the electrical shock. He was exposed to the action of a pile of 50 plates, by communications, through chains and metallic exciters, of the two extremities of the pile, with different points of the cheek affected. At the moment of contact, all the muscles of the face became convulsed, with heat, pain, &c. These endeavours repeated, during more than six months, have, by degrees, brought back the parts to their natural state.

Dr. Alibert has applied galvanism with still more decided success, to a priest attacked with hemiplegia. This patient, who lay in the wards of the Hospital of St. Lewis, has recovered the use of the palsied side, sufficiently to walk, almost without assitance, and to use his right arm as he wants it. The treatment has gone on for several months: the pile employed consisted of fifty plates of zinc and copper. I am trying the same apparatus upon a Swedish officer, for incomplete deafness, which has hitherto resisted all known applications, administered in different parts of Germany. Strong electrical shocks, recommended by Hufeland, had dispelled, in great measure, the hardness of hearing: but this amendment was only temporary: it ceased with the application of the remedy. The first trial of galvanism was attended with the same effect. The extremity of a conductor being placed in the exterior auditory duct of the right side (moistened with a solution of muriate of ammonia, as well as the pieces of cloth which made part of the pile) the left hand, dipped in the same liquid, touched a conductor placed at the copper pole: immediately an irritation, followed by painful prickings, was felt in the ear, the outer part of which became very red. The brain partook in the excitement the eyes flashed, and the effect was such, that after remaining a few minutes in the closed galvanic circle, the patient was taken with a sort of inebriation. I propose to direct, as has been done at Berlin, a more immediate irritation on the right ear, which is the deafest, by introducing behind the velum palati, on the guttural orifice of the eustachian tube, the button which is at the end of the conductor of the zinc pole; or else to make this extremity correspond with a denuded surface, by a blister behind the diseased ear.

To use galvanism, in paralysis of the bladder, it would be necessary to place the conductor of the zinc pole in the rectum, that of the other pole answering to a blister applied above the pubis, or else to the upper part of the thigh. In women, the vagina would be preferable to the rectum; the soft parts which perform the part of moist conductors fulfilling that office the better, the thinner they are. Galvanism is therefore an energetic stimulant of the vital powers; it may be employed, with great advantage, in all palsy both of sensation and of motion. It acts as stimulant, reddening the skin where it is applied, by determining thither the flow of blood, with heat. Monro could make his nose bleed at pleasure, by applying it to the pituitary membrane. I have made various experiments having in view to establish the efficacy of galvanism, in white swelling of the joints, and in ulcers which require excitement; such as those which are attended with a scorbutic affection, &c. in all these cases, it acts as a resolvent and as a tonic. I shall communicate, in my Surgical Nosography, the results of these attempts. Cases of asphyxia are those in which the greatest good may be hoped for from galvanism, provided the application be made before all the vital heat be extinct.

Those who would wish fuller details on galvanism, and on its possible application to the treatment of disease, will do well to consult the Complete History of Galvanism, by Professor Suë, the eulogium of Galvani, by Dr. Alibert, in the beginning of the fourth volume of the Memoirs of the Medical Society of Emulation, and the work of Dr. Aldini, nephew to the celebrated author of the discovery.

CLXXIV. *General view of the osseous system.* Man, as well as the other red-blooded animals (the mammiferæ, birds, reptiles, and fishes) has an internal skeleton, formed of a great number of bones articulated together, and set in motion by the muscles with which they are covered. The white-blooded animals have no internal skeleton, and are enveloped in hard, scaly, or stony parts, forming what is called their outer skeleton. some animals are entirely destitute of hard parts; this is the case with the zoophytes, some worms and insects. The internal structure of bones is composed of nearly the same materials in all animals: viz. gelatine and salts containing a calcareous basis. The external skeleton of white-blooded animals bears a much greater resemblance to the epidermis than to the osseous system of the red-blooded animals. Like the epidermis, it undergoes changes of decomposition and renovation. Thus, the lobster parts with its shell, every year, when the body of this crustaceous animal increases in size and it is replaced by a new envelope, which is at first very soft, and which gradually acquires the same consistence as the former. Lastly, the skeleton of birds differs from that of all other animals, in having its principal bones pierced by openings communicating with the lungs, and always filled with an air rarefied by the vital heat, which greatly assists in giving to them that specific lightness so essential to their peculiar mode of existence.

The osseous system serves as a foundation to the animal machine, yields a firm support to all its parts, determines the size of the body, its proportion, its form and attitude. Without the bones, the body would have no permanent form, and could not easily move from one place to another. When, from the loss of the calcareous earth to which they owe their hardness, these organs become soft, the limbs deformed, standing, and the different motions of progression, become after a time impossible. Such are the effects of rachitis, a disease of which the nature is well understood, though we are not the better informed with regard to the manner in which its causes operate, or the medicines which it requires.

The vertebral column forms the truly essential and fundamental part of the skeleton; it may be considered as the base of the osseous edifice, as the point in which all their efforts terminate, as the centre on which all the bones rest in their various motions, since every effort or shock, in any way considerable, is felt there. Moreover, it contains in the canal with which it is perforated, the cerebral prolongation, which furnishes most of the nerves in the body.

In order that it may support all the different parts, and at the same time, protect the delicate organ which it contains*, and adapt itself to the various attitudes required by the wants of life, it was necessary that the vertebral column should possess, besides great solidity, a sufficient degree of mobility; it possesses both these advantages, and owes the former to the breadth of the surfaces by which its bones are articulated together, to the size, the length, the direction and the strength of their processes, and to the great number of muscles and ligaments connected with it; it owes its freedom of motion to the great number of bones of which it is formed. Each single vertebra has but a slight degree of motion, but as they all have the power of moving at once, the sum of their individual motion added together, gives as the result a general motion which is considerable, and which is estimated by multiplying the single motion by the number of vertebræ.

The centre of the motions, by which the spine is extended or bends forward or backward, is not situated in the articulation of the oblique processes, as is maintained by Winslow, in the Memoirs of the Academy of Sciences for the year 1730, nor in the intervertebral substance. The extension and flexion of the vertebræ are not performed on two centres of motion, the one in the intervertebral substance, the other in the articulations of the articulating processes, as was imagined by Cheselden and Barthez, but on an axis crossing the bone between its body and its great aperture. The anterior part of the bone and its spinous process perform, around this imaginary axis, motions forming part of a circle, and which though limited are not the less marked; and in these motions, the articulating surfaces separated by the intervertebral substance are brought into close contact, and this substance is compressed, while the oblique processes move on one another, and tend to part from one another; this is what happens in bending the trunk, while, in straightening it, the anterior surfaces are removed from each other, the posterior surfaces approach, come closer and closer, together, and finally touch throughout the whole of their extent, when the extension of the trunk is carried as far as the spinous processes will allow.

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* The peculiar manner in which the vertebræ grow, is itself accommodated to the delicacy of the spinal marrow; consisting, for a considerable length of time, of several pieces divided by cartilages, the circumference of the opening in these bones, becomes enlarged, with the enlargement of the spinal marrow, as we grow older. The circumference of the foramen of the occipital bone and that of the first vertebræ which correspond to the thickest part of the spinal marrow, is, on that account, formed of four distinct pieces separated by cartilages in the first of these bones, and of five pieces in the other.

The use of the ridge of projections which arise from the posterior part of the vertebræ, is to limit the bending of the trunk backwards, and to enable the muscles which straighten it, to act with a more powerful lever. When, from the habit of an habitually erect posture, these processes have been prevented from growing in their natural direction, the trunk may be bent backward to such a degree, that the body forms, in that direction, an arc of a circle. It is thus, that they train, from the earliest infancy, the tumblers who astonish us by the prodigious suppleness of their loins, in bending backward so as to change the natural direction of their spinal processes.

It was of consequence, that the motions of the vertebral column should take place, at once, in a great number of articulations, as the curvatures are thus less sharp, and thus the organization of the spinal marrow, which is very delicate, is not injured. The fibro-cartilaginous substances which connect together the bodies of the vertebræ, between which they lie, possess a remarkable degree of elasticity, like all bodies of the same kind, and support, in a favourable manner, the weight of the body. When the pressure which they experience is long continued, they somewhat yield, and diminish in thickness, and this effect taking place, at the same time, in all the intervertebral substances, our stature is sensibly lowered. The body is, on that account, always shorter in the evening than in the morning, and this difference may be considerable, as is mentioned by Buffon to have been the case in several instances. The son of one of his most zealous coadjutors (M. Gueneau de Montbeillard, to whom is due the greatest part of the natural history of birds), a young man of tall stature, five foot nine inches when he had reached his complete growth, once lost an inch and a half, after spending a whole night at a ball. This difference in the stature depends, likewise, on the condensation of the cellular adipose tissue at the heel, which forms, along the whole of the sole of the foot, a pretty thick layer.

The thigh bone is longer in man than in quadrupeds, and this relative length of the thigh, gives him exclusively the power of resting his body by sitting.

The tibia is the only one of the bones of the leg which affords a support to the body. The fibula, situated at its outer part, too thin and slender to support the weight of the body, is of use merely with regard to the articulation of the foot, on the outside of which it lies. It supports the foot, and prevents its starting outward by too powerful an abduction. The foot, in this motion, is forced against the fibula which is bent outwardly, the more so when the person is advanced in years, and has, therefore, called into frequent action this force of resistance. Animals that climb, as the squirrels, whose feet are in a continual state of abduction, have a very large and strongly curved fibula.

The number of the parts which form the feet, besides giving to these parts a greater solidity, is further useful in preventing the foot from being too violently shaken by striking the ground, in our various motions of progression. In leaping from a height, we en-

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* This curvature is well marked in the chefs-d'œuvre of antique sculpture, and gives to the lower part of the leg, in our most beautiful statues, a thickness which does not at all agree with our present notions of elegance of form. This seems to me to prove, that the beautiful is not invariable, as has been asserted by many philosophers; and that ideal perfection is not precisely the same in all ages, in nations equally civilized. The truth of this observation may be proved by the Apollo Belvedere; his knees are rather large and close together, and this form is the most beautiful representation of Nature, which gives to the femur an obliquity inwards, the knees not being perfectly straight, and without any disproportion between the calf and the thin part of the leg.

deavour to fall on our toes, that the force of the fall may be broken, by being communicated to the numerous articulations of the tarsus and metatarsus, and may not affect the trunk and head with a painful and even dangerous concussion. It is well known, that when, in falls, the whole sole of the foot strikes against the ground, fracture of the neck, of the thigh bones, and concussion of the brain and other organs, is not an unlikely consequence.

CLXXV. *Structure of the bones.* Whatever difference there may, at first sight, seem to exist, between a bone and another organ, their composition is the same. Its structure consists of parts that are perfectly similar, with the exception of the saline inorganic matter which is deposited in the cells of its tissue, which gives it hardness and that solidity which constitutes the most striking difference that distinguishes it from the soft parts. This earthy substance may be separated, by immersing the bone in nitric acid diluted in a sufficient quantity of water. It is then found, that it is a phosphate of lime which is decomposed, by yielding to the nitric acid its calcareous base. The bone, thus deprived of the principle to which it owes its consistence becomes soft, flexible, and resembles a cartilage, which is resolvable, by long maceration, into a cellular tissue similar to that of the other parts. This tissue contains a pretty considerable number of arteries, veins, and lymphatics. The bones are, therefore, mere cellular parenchymas whose areolæ contain a crystallized saline substance, which they separate from the blood, and with which they become incrusted, by a power inherent in their tissue and peculiar to it. The same result may be obtained by inverting the analysis. If a bone is exposed to boiling heat, for a few hours, in Papin's digester, all its organized parts become dissolved, melt, and furnish a quantity of gelatine, after which there remains only an inorganic saline concretion; which may, likewise, be obtained in a separate state by calcining the osseous part. The different proportions of the saline to the organized part, vary considerably at different periods of life; the bones of the embroyo are, at first, quite gelatinous. At the period of birth, and during the first years of life, the organic part of the bone is in greater proportion; the bones are less apt to break, more flexible, possessed of more vitality, and, when fractured, are more speedily and more easily consolidated. In youth, the two constituent parts are nearly in equal quantities; in adults, the calcareous earth* alone forms two thirds of the osseous substance. At last, gradually increasing in quantity, it displaces, in old people, the part that is organized; hence their bones are weaker, more liable to fracture, and unite less readily. One may therefore say, that the quantity of phosphate of lime deposited in the bones, is in the direct ratio of the age; and that, on the contrary, the energy of the vital faculties of these organs, their flexibility, their elasticity, their aptitude to become consolidated, when their continuity is destroyed by accidents, are in an inverse ratio.

Anatomists distinguish in bones three substances, which they term compact, spungy, and reticular. The first, which is the hardest, collected in the centre of the long bones, where the greatest stress of the efforts applied to their extremities rests, gives to the bone the strength which it required. Its formation has been explained, in various ways; some have maintained that it owed its hardness to the pressure applied to its middle part by the two extremities of the bone; in the same manner as the stalk and the roots press against the *collet*† of a plant. Haller thinks it is caused by the pulsations of the nutritious arteries which penetrate into the long bones, at their middle part; why then is their structure different at their extremities where they receive arteries equally large and more numerous? In the process of ossification, this substance appears first in the centre of the long bones; and this confirms the assertion of Kerkringius, who says, that our long bones begin to ossify, in those points where they have to resist the greatest pressure.

The spungy substance is found within the short bones, and at the extremities of the long ones, where its accumulation is attended with two advantages, that of giving to the bone, without increasing its weight, a considerable size, by which it may be articulated with the neighbouring bones, by wide surfaces, so as to give firmness to their connexions; this conformation is attended with another advantage, that of avoiding the parallelism of the tendons which pass over the joints, in order to enlarge the angle of their insertion in the bones, and to give more efficacy to muscular action. The mechanical hypotheses proposed by Haller and Duhamel, to explain the formation of this spungy substance, are very unsatisfactory, especially if it be considered, that in the gelatinous bones of the embryo, the place that is to be occupied by the spungy substance, viz. the extremities of the long bones, of which the rudiments begin to appear, are larger than any other part. All the cells of this spungy substance communicate with one another, they are lined by a very fine membrane, and contain the medullary fluid. The laminæ which cross each other, in various directions, and which form the parietes of the cells, become fewer in number and thinner; the spungy tissue expands in approaching the middle part of the bones and forms (within the medullary canal, of the compact substance) a reticular tissue, the use of which is to support the membranous tube containing the marrow.

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* By chemical analysis of the bones, there have been discovered several other saline substances mixed with the phosphate of lime; but as this salt alone constitutes the greatest part of the substance which gives to the bones their hardness, I thought that it would be useless to enter into minute details, in a work of this kind, by giving an account of the more recent chemical analyses.

† The part where the stem joins the root. T.

These three substances, notwithstanding their unequal density, are, in reality, but one and the same substance differently modified. The reticular and spungy differ from the compact, in containing less phosphate of lime, and in having a rarer and more expanded tissue. In other respects, those changes in the osseous tissue which constitute the laminated exostoses, the conversion of the bones, by acids, into a flexible cartilage, which, by maceration, may be reduced into cellular tissue, prove that these three substances are truly identical, and differ from each other, only by the degrees of closeness of their texture and the quantity of calcareous phosphate deposited in the meshes of their tissue.

The compact substance appears to consist of concentric laminæ strongly united together, and to be formed of fibres, arranged longitudinally, and in juxta position. In proof of this arrangement, it is usual to mention the exfoliation of bones exposed to the air; but these laminæ detached from an exfoliating bone, merely prove that the action of the disease, the air, heat, or any other agent, by applying itself successively to the different layers of bone, produces between them a separation which did not exist in health, and determines their falling off in succession. Certain parts, in which this lamelated structure does not exist, may, in like manner, undergo the same kind of decomposition. Thus, Lassone saw a piece of human skin that had been preserved, for a considerable length of time, into a vault, separate into layers of extreme minuteness.

The vital principle which exists, in a smaller degree, in the bones than in other parts, seems to animate, to a certain degree, their different substances. Proportioned to the number of vessels which are distributed to it, life is more active in the spungy tissue; hence, in fracture of this part, fleshy granulations and callus form more quickly. Caries, likewise, advances more rapidly, and it is more difficult to interrupt its progress.

CLXXVI. *Of the uses of the periosteum and of the medullary juices.* Whatever be the situation, the size, the shape, and the composition of bones, they are all enveloped by the periosteum, a whitish, fibrous, dense and compact membrane, to which are distributed the vessels which penetrate into their substance. The periosteum is a membrane perfectly distinct from the other soft parts, and from the bone itself, to which it adheres by means of vessels and of cellular tissue, which pass from the one to the other, the more closely, as we are more advanced in years. The cellular and vascular fibres which penetrate into the substance of the bone, establish a very close sympathetic connection between its periosteum and the very delicate membrane that lines its internal cavity, which secretes the marrow, and is called the internal periosteum. On destroying the internal medullary membrane, by introducing a stylet within the cavity of the bone, its external layers swell, are detached from the inner ones, and form, as it were, a new bone around the sequestra. The new bone is not formed by the ossification of the periosteum, as was maintained by Troja. This membrane has no more to do with the formation of the new bone, in necrosis, than with that of the callus in fracture. The periosteum, covering a bone affected with necrosis, does not become thicker, and does not acquire more consistence; nor is there formed around the ends of a fractured bone, a ring to keep them cemented, as was the opinion of Duhamel; an opinion recently brought forward in a work in which the author seems to delight in reviving errors that have been abandoned for ages. Destitute of nourishment, dead and dried up in this artificial necrosis, the sequestra moves in the centre of the new osseous production, from which it may be extracted by a perforation made for that purpose. It is owing to the same sympathy, that the dull nocturnal pains which are occasioned by the warmth of the bed, in patients in the last stages of the venereal affection, and which appear to have their seat in the centre of the long bones, occasion a swelling of these bones and of the periosteum.

The use of the periosteum is to regulate the distribution of the nutritious juices of bones, since, whenever it is removed, granulations arise, in an irregular manner, on the spot that is bared. This quality is, besides, common to all fibrous membranes whose destruction is followed by excrescences from the organs which they cover. The same takes place, whenever trees are partially stripped of their bark. It has been erroneously believed, that the periosteum, in the same way as the bark of plants, contributes to the growth of the bones, by the sucessive induration of its internal laminæ.

The marrow which fills the central cavity of the long bones; and the medullary fluid contained in the cells of the spungy substance, bear the greatest analogy to adeps, both in their chemical composition and in their uses (CVI). The proportion of these two fluids is uniformly relative. In very thin people, the bones contain a marrow that is thin and watery, and though this fluid always fills the internal cavities of these organs, whose solid parietes cannot collapse, it contains much fewer particles in the same bulk: and its quantity, like that of the fat, is in fact diminished. It is the product of arterial exhalation, and does not serve to the immediate nutrition of the bone, as was thought by the ancients; at least, it does not answer that purpose solely, for, in the numerous class of birds, the bones contain cavities for air, and are destitute of this fluid. It is difficult to determine the use of the marrow and of the medullary fluid; may they not answer the purpose of filling the cavities which Nature has formed in the bones, so as to render them lighter? Does a part of these fluids exude through the cartilages of the joints, and mix with the synovia to increase its quantity, and to lessen the friction of the articulating surfaces? If this transudation may take place after death, why might it not take place, when all the parts are in a state of vital warmth and expansion?

CLXXVII. *Of the articulations, the articulating cartilages and ligaments, and the synovial fluid.* The articulations of the different parts of the skeleton are not all intended to allow of motion, several, as the serrated and squamous sutures, and the gomphosys, are entirely without motion and are, on that account, termed *synarthrosis.* All the other articulations, whether the bones are in immediate contact (diarthrosis of contiguity), whether they are united by a substance interposed between them (diarthrosis of continuity or amphiarthrosis), are endowed with a certain degree of mobility. I shall speak merely of the moveable articulations; whether they allow of extensive motions and in every direction (diarthrosis orbicularis) or whether the bones move only in two opposite directions (alternate diarthrosis or ginglymus) by forming an angle, (angular ginglymus), or by executing, on each other, motions of rotation (lateral ginglymus).

In all the articulations, the osseous surfaces are covered by laminæ of a substance less hard than that of the bone. These are the articulating cartilages which answer the two purposes of giving to the ends of the bones, the degree of polish necessary to their slipping freely, and to facilitate motion, by the considerable degree of elasticity which they possess. Morgagni has shewn, that of all animal substances, cartilages possess most elasticity; their structure is very different from that of the bones, even when these are yet cartilaginous; for, these articulating cartilages do not become ossified, even in persons greatly advanced in years*. They are formed of very short fibres disposed according to the length of the bone, strongly compressed against each other, and united by other transverse fibres. This vertical direction of the greatest part of the cartilaginous fibres, demonstrated by Lassone, is very favourable to their elastic re-action. The capsular ligament is reflected over them, becomes very thin, and is lost in their perichondrium, according to Bonn, Nesbith, and other anatomists.

Besides the cartilages which surround the extremities of bones, there are found, in certain articulations, fibro-cartilaginous laminæ lying between the articulating surfaces. These connecting ligaments may be observed in the articulation of the lower jaw to the temporal bones, of the femur with the tibia, and of the sternum with the clavicle; and all such articulations perform a great number of motions, as is the case with the jaw, or suffer considerable pressure, as the joints of the knee and sternum. The latter, which has a very slight degree of motion, being the point in which terminate all the efforts of the upper extremity, required this apparatus to lessen the effect on the trunk, the motion that is given being, in part, lost, in the action of the articulating cartilage.

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* Sometimes, however, these cartilages are destroyed, the denuded bone then becomes polished by friction, and as hard as ivory

I shall not repeat what has been already said of the secretion of the fluid that lubricates the articulating surfaces, that facilitates their motion and keeps them in contact. Its quantity is in direct ratio of the extent of these surfaces and of the membranous capsule in which they are contained; it is, likewise, proportioned to the frequency of motion which each articulation allows.

Synovia is the name that is given to the fluid prepared by the glandulo-cellular bodies in the vicinity of the articulations, and secreted by the membranous capsules which surround them, and are reflected over the articulating extremities of the bones whose cartilages they cover; so that, as was shewn by Bonn, about the middle of the last century, these extremities cannot be said to be contained within the cavity of the capsule, which is closed, in every direction, any more than the abdominal viscera within that of the peritoneum. The synovia is heavier than common water, quite colourless, and more viscid than any other animal fluid. It contains a considerable quantity of albumine which, according to Margueron, who first gave a tolerably accurate analysis of synovia, is found in a particular state, and much disposed to concrete into filaments, on the addition of acids. Besides, it contains muriate and carbonate of soda and phosphate of lime, the whole dissolved in water, which forms about three-fourths of its weight.

CLXXVIII. *Theory of anchylosis.* Motion may be considered as the proper stimulus of the synovial secretion; and a moveable joint, as is justly observed by Grimaud, is as a centre of fluxion towards which the fluids rush, in every direction, in consequence of the irritation which friction determines. If the joint remains long without motion, the synovia is secreted in smaller quantity, and this lessens gradually; it may even happen that the articulating surfaces, remaining long absolutely motionless, lose their moisture, and from the want of the fluid which should lubricate them, bring on irritation and adhesive inflammation in each other, either from increased action of the vessels of the perichondrium. or as is believed by Nesbith, Bonn, and others, from an inflammatory state of the fold, which is reflected from the capsule of the joint over the ligament.

This is the manner in which the disease, termed anchylosis, comes on, a disease improperly ascribed to the congestion of the soft parts, and especially of the ligaments surrounding the articulations. In fact, when in a fracture of the thigh or leg, about the middle of the length of one of these bones, and consequently, at the greatest possible distance from the knee joint, the circumstances of the case require that the bandages should be kept on the limb, a considerable time, the joint loses its power of motion, recovers it with difficulty, and sometimes not at all. I have at present before me, the case of a man in whom a scorbutic affection has delayed, to such a degree, union of the bone, after a simple fracture of the femur, about the middle of the bone, that it has been found necessary to continue, for seven months, the use of splints. In the course of so long a state of inaction, the soft parts have lost the habit of moving, and the knee is, almost completely, anchylosed.

Whenever, on account of any complaint, one has been confined to bed, the first attempts to walk are painful, difficult, and attended by a marked crepitus in the knee, denoting clearly the want of synovia. On the other hand, if the joint is examined in a person who before death has been long without motion, the articulating surfaces will be found rough and dry, with evident marks of inflammation. Flajani mentions the case of a patient who died after having been three months in bed, in an almost motionless state. Externally, the knees did not appear to have been injured, and yet he could not bend his knee joint. On opening the joint, it was found that the articulating surfaces had grown together ; the posterior part of the patella adhered to the condyles of the femur, and it was necessary to use a scalpel to detach these parts from each other. I have frequently observed the same appearance, in dissecting the knee joint of persons who died while labouring under white swelling, with or without ulceration. The anchylosis which invariably attends this affection, evidently arises from the absolute rest of the diseased joint.

Anchylosis from want of motion, and consequently from want of synovia, is not always a partial affection limited to one or two joints; sometimes, it affects several at once, as in the case of the patient whose skeleton was presented by M. Larrey to the museum of the School of Medicine at Paris. One of the most remarkable cases of universal anchylosis of the joints, is that lately communicated to the National Institute by M. Percy : the patient was an old cavalry officer, who was subject to fits of the gout and whose articulations, even that of the lower jaw, became stiff and completely lost all power of motion, so that, towards the latter end of his wretched existence, he could not be moved without feeling severe pain in his anchylosed joints.

From this explanation may be conceived the advantage of moving the lower extremity, when, after a fracture of the leg, the ends of the bone have become sufficiently united to prevent their being displaced. These motions, which are of indispensable necessity in all fractures of the femur, of the tibia, and especially of the patella, are much better calculated to prevent anchylosis, than the various resolvent remedies which are commonly employed, as plaisters of soap, vigo, cicuta, diabotanum, diachylon, pumping, bathing, and fumigations, which, however, should be used in combination with a moderate exercise of the limb, in order to obtain the most complete success.

The gout affects those joints which are most subject to motion, and on which there is the greatest pressure. The first attacks, as Sydenham observes, come on in the joint of the great toe with the first metatarsal bone, an articulation which bears the weight of the whole body, and which is most called into action, in the various motions of progression.

The muscles which pass over the joints give them much greater security than the lateral ligaments. In fact, if the muscles become palsied, the mere weight of the limb stretches the ligaments, which give way, become elongated, and allow the head of the bone to escape from its glenoid cavity. It is, in this manner, that a loss of motion, and atrophy of the deltoid muscle, are attended with a luxation of the humerus: the orbicular ligament of the articulation of this bone with the scapula, being incapable of retaining its head within the glenoid cavity. The spinal column, when dissected and deprived of all but its ligamentous attachments, gives way under a weight much smaller than that which it would have supported, before being stripped of the muscles which are connected with it.

CLXXIX. *Of standing.* This is the name given to the action by which man holds himself upright on a solid plane. In this erect position of all our parts, the perpendicular line, passing through the centre of gravity* of the body, must fall on some point of the space measured by the soles of the feet. Standing is most firm when, on prolonging the line of the centre of gravity of the body, it falls on the base of sustentation (I call thus the space defined by the feet, whether close or apart); but this line may tend to exceed it, without our necessarily falling, the muscular action soon restoring the equilibrium which is deranged by the altered direction of this line. But if the lower extremity of the line, by being prolonged, should fall without the limits of the base of sustentation, a fall is unavoidable on the side towards which this line inclines*.

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* The centre of gravity, in the adult, is situated between the sacrum and pubis.

If the body is inclined backwards, so that there is a danger of a fall on the occiput, the extensor muscles of the leg contract powerfully, to prevent the thigh from bending, while other powers bring forward the upper parts, and give to the prolonged line of the centre of gravity a different direction; and if, in proportion as the extensors of the leg are brought into action, its inclination be increased to such a degree that nothing is capable of keeping up the body, which its own weight tends to bring to the ground, these muscles, by a motion proportioned to the quickness of the fall, will increase their efforts to prevent it, and and may be able, in that violent contraction, to snap asunder the patella, as I have explained in a Memoir on the fractures of that bone.

I think it useful to insist, more than has been done hitherto, on the mechanism by which the human body is supported in the erect posture; for, a knowledge of that mechanism facilitates the explanation of the motions of progression. To walk, or to run, the body must be upright; now, when it is known by what power the centre of gravity of the body is maintained perpendicular on the plane which supports it, it will be easy to understand the different ways in which it changes its place, in the course of locomotion.

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* "*Quotiescumque linea propensionis corporis humani cadit extra unius pedis innixi plantam, aut extra quadrilaterum, comprehensum a duabus plantis pedum, impediri ruina, a quocumque musculorum conatu, non potest.* Borelli, Prop. 140.

The firmness of the attitude, in standing, depends, therefore, in part, on the breadth of the feet and on their distance; hence, it is much more tottering when we stand on one foot, and we are, under such circumstances, obliged to be perpetually struggling, to prevent the centre of gravity from falling out of the narrow limits of the base of sustentation.

Let us first inquire into the question so long agitated, whether man is intended to support himself and to walk on his four limbs, in the early period of his existence after birth?

CLXXX. An upright position would be to man a state of rest, if his head were in a perfect equilibrium on the vertebral column, and if the latter, forming the axis of the body and supporting equally, in every direction, the weight of the abdominal and thoracic viscera, fell perpendicularly on the pelvis placed horizontally, and, in short, if the bones of the lower extremities formed columns set perpendicularly under their superincumbent weight; but not one of these circumstances is to be observed in the human body: the articulation of the head does not correspond to its centre of gravity; the weight of the thoracic and abdominal viscera, and of the parietes of the cavities in which they are contained, rests, almost entirely, on the anterior part of the vertebral column. The vertebral column is supported on an inclined base, and the bones of the inferior extremities, which are connected to each other by convex and slippery surfaces, are, more or less, inclined towards one another. It is therefore necessary, that an active power* watch incessantly, to prevent the fall which would be the natural consequences of their weight and direction.

This power resides in the extensor muscles which keep the parts of our body in a state of extension, the more perfect, and which render our erect posture the firmer, as they are endowed with a more considerable power of antagonism, and as our parts are naturally less disposed to flexion; and, besides, as we have seen (CLXVI), these powers are not sufficient to balance those whose action is directly opposed to their's.

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* An upright posture is not, in all animals, as it is in man, the consequence of an effort. This is proved by the following fact observed by M. Dumeril. The sea fowl and especially the waders (Grallæ Lin) as herons and storks, forced to live in the midst of marshes and muddy waters, in which they find the fishes and reptiles, on which they feed, have long since afforded matter of surprize to Naturalists, by the length of time they can remain motionless in an erect posture. This singular power, so necessary to animals obliged to expect their prey, more from chance than from industry, they owe to a peculiar conformation of the articulation between the leg and thigh. The articulating surface of the thigh bone, as M. Dumeril had an opportunity of observing in a stork (*Ardea ciconia*, Linn) contains, in its centre, a depression, into which there is received a projection of the tibia. To enable the animal to bend its leg, that projection must be disengaged from the depression into which it is lodged, and this is resisted by several ligaments which keep the leg extended in standing, in flying, and other propressive motions, without the assistance of the extensor muscles.

The relative weakness of the extensor muscles is not the only obstacle which renders impossible an erect posture, at an early period of life. Other causes, into which we are about to enter, concur in unfitting the new born child for the exercise of that faculty.

The articulation of the head to the vertebral column being nearer the occiput than the chin, and not corresponding to its centre of gravity, its own weight is sufficient to make it fall on the upper part of the chest. It is the more disposed to fall forward, from its greater bulk, and, as in a new born child the head is much larger in proportion than the other parts of the body, and as its extensor muscles partake of the greater weakness of that set of muscles, it falls on the fore part of the chest, and in its fall draws the body after it. The weight of the thoracic and abdominal viscera tends to produce the same effect.

Growth always proceeds from the upper to the lower parts, and this law, which operates uniformly, compleatly eludes every kind of mechanical explanation. It is otherwise, with regard to the effects which result from this unequal growth in respect to the erect posture. The inferior limbs, which serve as a base to the whole edifice, being imperfectly evolved at the period of birth, the upper parts placed on these unsteady foundations, must necessarily fall and bring them down with them.

The relative weight of the head, of the thoracic and abdominal viscera, tends, therefore, to bring forwards the line in the direction of which all the parts of the body press on the plane which supports it, and this line should be exactly perpendicular to that plane to enable the body to be perfectly erect: the following fact proves this assertion; I have observed, that children, whose head is very large, whose belly projects, and whose viscera are loaded with fat, have much difficulty in learning to stand; it is only about the end of their second year, that they dare trust to their own strength, and then they meet with frequent falls, and have a continual tendency to go on all fours.

The vertebral column, in the child, does not describe, as in the adult, three curves alternately placed, in opposite directions. It is almost straight, and yet presents in the direction of its length a slight curvature, the concavity of which looks forwards. This incurvation, which depends solely on the flexion of the trunk while in the womb, is accordingly more marked, the nearer the child is to the time of his birth.

It is well known that the curvatures, in opposite directions to the vertebral column, add to the firmness of the erect posture, by increasing the extent of the space within which the centre of gravity may move, without being carried beyond its limits. With regard to that use, the vertebral column may be considered, as defined by two lines drawn from the anterior and posterior part of the first cervical vertebra, to the sacro lumbari symphysis. These two lines, very near to each other at their upper part, and, below, at a distance from each other, would be the chords of arcs and the tangents of the curves, formed by the vertebral column. So that this column may be considered as having a fictitious thickness greatly exceeding its real bulk.

In the new born child the want of alternate curvatures not only contracts the boundaries within which the centre of gravity may be varied, but the direction of the only curvature which exists favours the flexion of the trunk, and consequently the inclination forward of the centre of gravity, and the tendency to fall in that direction. This inflexion of the vertebral column in the fœtus and in the young child resembles that observed in several quadrupeds*.

The disadvantage resulting from the want of alternate curvatures in the vertebral column of the child is further increased, by the total absence of spinous processes. It is well known, that the principal use of these projections, is to place the power at a distance from the centre of motion of the vertebræ, to increase the length of the lever by which it acts in straightening the trunk, and thereby to render its action more efficacious. At the period of birth, the vertebræ have no spinous processes, they afterwards grow from the place at which the laminæ of those bones are united, by means of a cartilaginous substance, which compleats the posterior part of the vertebral canal. The muscles destined to keep the trunk erect, weakened by its constant flexion during gestation, lose, besides, a great deal of their power, from the unfavourable manner in which they are applied to the part on which they are to act.

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* This curvature is very distinctly marked in swine. The back of these animals is remarkably prominent, and this form, necessary to enable the vertebral column to support the immense weight of their abdominal viscera, has a considerable influence on the mechanism of their motions of progession. When frightened by any noise, they spring in bounds, and it is easy to perceive that, at each spring, the spine becomes arched and then straightens itself, and that their motion when rapid is effected by the alternate tension and relaxation of their spinal arch.

The flexion of the head does not depend merely on its very considerable weight, but, likewise, on the want of spinous processes in the cervical vertebræ, since the principal motions of the neck are performed, not so much by articulation with the atlas, as by the union of the other cervical vertebræ.

The pelvis of the child is but imperfectly evolved, and its upper outlet very oblique, The viscera, which are afterwards to be contained within its cavity, are, for the greater part, situated above it. This obliquity of the pelvis would require a perpetual straightening of the vertebral column to prevent the direction of the centre of gravity from obeying its natural tendency forward. On the other hand, the vertebral column, resting on a narrow pelvis, is less firmly fixed, and may more readily be drawn beyond the limits of the base of sustentation. Lastly, the limited extent of the pelvis, together with its obliquity, causes the ill supported abdominal viscera to fall on the anterior and inferior part of the parietes of the abdomen, and favours the fall of the body in the same direction.

The patella, which answers the double purpose of giving firmness to the knee joint, in front of which it is placed, and of increasing the power of the muscles of the leg, by placing them at a distance from the centre of motion in that articulation, and by increasing the angle at which they are inserted into the tibia, as yet does not exist in new born children. The tendinous portion of the extensors of the leg, where the patella is hereafter to be formed, is merely of a more condensed tissue, and of a cartilaginous hardness.

The want of a fulcrum is attended with a continual disposition in the leg, to bend upon the thigh, and the parallel direction of its extensor muscles, occasions a complete loss of their effective power. Then their antagonizing muscles induce a flexion of that limb, which is the more considerable, as it is but imperfectly limited by the tendon which is situated at the fore part of the knee.

The length of the os calcis, the extent of its projection beyond the inferior extremity of the bones of the leg, tend to give firmness to the erect posture, by increasing the length of the lever, by which the extensors of the foot act on the heel, and, as, in the new born child, this bone is shorter and less projecting, the power of these muscles, whose insertion is very near the centre of motion of the articulation of the foot, is greatly diminished.

The feet, in man, are broader than those of any other animal, and to this breadth of the surface of the base on which he rests, he, in great measure, owes the advantage of being able to support, on one leg or on both, the weight of his body, in standing and in the different motions of progression; while the other mammalia cannot support themselves, at least only for a very limited time, without resting on three of their extremities. When I say that from the extent of his feet, the body of man does, of all animals, rest on the broadest surface, I do not take into account the space which those parts include between them when apart from each other. In fact, the space which is measured by the feet, is much greater in quadrupeds than in man. Nature has made up for the disadvantage arising out of the smallness of their feet, by the distance at which they are placed; and if that form disables them from standing on two feet, it gives firmness to their peculiar mode of standing.

The feet of the ourang outang, which, in the general structure of his organs, bears so striking an analogy to the human species, resemble a coarsely formed hand, better fitted to climb the trees on which that animal seeks his food, than to the purposes to which man applies his hands. Thus the erect posture which he, at times, assumes, is neither the most convenient nor the most natural to him. And, according to a philosopher who speaks on the authority of several travellers, if a sudden danger obliges him to make his escape, or to leap, he drops on all fours, and discovers his real origin; he is reduced to his own condition, when he quits that unnatural attitude, and discovers in himself an animal, which, like many a man, has no better quality to recommend him than a specious disguise.

The feet are the parts least developed in the new born child: his body is insecure on that narrow basis; the prolongation of the line of his centre of gravity, which so many other causes tend to carry beyond that base, will be the more inclined to fall beyond it, from its small extent. The greater number of the differences which have just been examined, depend on the mode of nutrition in the fœtus. The umbilical arteries bring to the mother the blood which the aorta carries towards the lower parts, and only a few small branches are sent to the pelvis and to the lower extremities. Thus, the developement, which almost uniformly bears a proportion to the quantity of blood sent into organs, is but imperfect in those parts at the time of birth, while the head of the trunk and upper extremities are evolved much more considerably.

The new born child, therefore, resembles quadrupeds in the physical arrangement of his organs. This analogy is the more marked, the nearer the fœtus is to the period of his formation, and it might be laid down as a general proposition, that organized beings resemble one another more closely, the nearer to the period of incipient existence, they are examined. The differences which characterise them become apparent, in proportion to the progress of evolution, and they are more and more distinct, as the acts of life are repeated in the organs which it animates.

The unequal distribution of power in the muscles, and the unfavourable disposition of the parts to which these powers are applied, render it impossible for the infant to stand upright, that is, to keep the mean lin e of direction of his body nearly perpendicular to the plane which supports it. But in proportion as he advances in age, the preponderance of the flexors over the extensors ceases to be in excess. The proportionate size of the head and of the thoracic and abdominal viscera diminishes. The curvatures of the vertebral column begin to be distinguishable, the spinous processes of the vertebræ are evolved; the breadth of the pelvis is increased, and its obliquity lessened; the patella becomes ossified, the os calcis juts out backwards, the relative smallness of the feet ceases. By degrees the child learns to stand, resting on both or only on one of his feet; his eyes naturally directed towards heaven, a noble prerogative which, if one might believe Ovid,* is possessed by man alone of all the animals.

Man is of all animals the only one that can stand upright and walk in that attitude, when his organs are sufficiently evolved. Let us now point out some of the principal causes to which that privilege is to be ascribed.

CLXXXI. Though the articulation of the head to the cervical column does not correspond either to its centre of magnitude, or to its centre of gravity, and though it is nearer to the occiput than to the chin, its distance from the latter is much smaller in man, than in the monkey and other animals, whose foramen magnum is, according to Daubenton, placed nearest to the posterior extremity of the head, when they resemble man the least. The head, therefore, is very nearly in equilibrio on the column which supports it; at least to keep it in that position, a very slight power is required, while the head of a quadruped, which has a constant tendency towards the ground, requires to be supported by a part capable of a great and continued resistance. This purpose is answered by the posterior cervical ligament, so remarkable in those animals, attached to the spinous processes of the vertebræ and to the protuberance of the occipital bone, which projects much more in them than in the human species, in whom instead of a posterior cervical ligament, there is found a mere line of cellular substance, dividing the nape of the neck into two equal parts.

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* *Os homini sublime dedit, cœlumque tueri*
Jussit, et erectos ad sidera tollere vultus.

These verses may be much more justly applied to the fish, called by naturalists *Uranoscopus.* Its eyes are urned upwards, and constantly look towards the heavens.

The alternate curvatures of the vertebral column, the breadth of the pelvis and of the feet, the great power of the extensors of the foot and thigh*, all these favourable conditions, observable in man, are wanting in animals; but as, in the latter, every thing concurs to prevent their being capable of standing on two feet, in man every thing is so disposed, as to render it very difficult for him to rest on his four extremities. In fact, independently of the great inequality which there is between his upper and lower limbs, a difference of length which, being less sensible in early life, makes it less uneasy for a child to walk on his hands and feet, these four limbs are far from affording the body an equally solid support. The eyes being naturally forwards, are, in that attitude, directed towards the earth, and do not embrace a sufficient space.

We cannot, therefore, agree with Barthez, that man, during infancy, is naturally a quadruped, since he is then but an imperfect biped: (CLXXX) nor can we admit that man might walk on all fours, all his life, if he were not broken of the bad habit which he learns in infancy.

CLXXXII. Very little has been added to what Galen has said in his admirable work on the structure of parts, relative to the respective advantages attending the peculiar conformation and structure of the upper and lower limbs. It is easy to see, that in combining, as much as possible, strength and facility of motion, Nature has made the former predominate in the structure of the inferior extremities, while she has sacrificed strength to facility, to precision, to extent, and rapidity of motion, in the upper extremities.

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* These muscles form the calf of the leg and the buttocks; in no animal are these masses of flesh more prominent than in man.

To convince oneself of the truth of what has been stated, it is sufficient to compare, under the two relations* of the resistance of which they are capable, and of the motions which they allow, the pelvis to the shoulder, the thigh to the humerus, the leg to the fore arm, and the foot to the hand.

The inferior extremities, if examined when the bones are covered with the soft parts, will present the appearance of an inverted cone or pyramid, which, at first sight, appears contrary to the object which Nature had in view; but if the bones be stripped of their fleshy coverings, these solid supports will be seen to represent a pyramid, whose base is at the lowest part and formed by the foot, and which decreases in breadth upward from the leg, formed by the union of two bones, towards the thigh, consisting of only one bone.

If it be asked why the inferior extremities are formed of several pieces, detached and placed one above the other, it will be found that they are thereby much more solid, than if formed of one bone, since, according to a theorem, demonstrated by Euler† two columns containing the same quantity of matter and of equal diameter, have each a solidity in inverse ratio of the squares of their height: in other words, of two columns, containing the same materials, of equal diameter, and of unequal height, the smaller is the stronger.

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* See the anatomical observations on the neck of the thigh bone, which I have prefixed to a memoir which bears the title of *Dissertation anatomico-chirurgicale sur les fractures du col du femur.* Paris, an VII.

† *Methodus inveniendi lineas curvas.*

Nature has, therefore, increased the number of these columns in the extremities of quadrupeds, by raising their heel and the different parts of the foot, whose bones she has lengthened, to make of them so many secondary legs. These numerous columns placed above one another, are alternately inclined, and in a state of habitual flexion, in the quadrupeds remarkable for swiftness in running or for their power in leaping, as in the hare and squirrel, while in the ox, and especially in the elephant, they are all placed vertically, so that the enormous mass of the latter rests on four pillars, the different pieces of which are short, and so slightly moveable on one another, that, as Barthez observes, Saint Basil has adopted the error of Pliny, Ælian, and several other writers of antiquity, that there are no articulations in the legs of that monstrous animal.

The long bones, which by their union form the inferior extremity, contain a cavity which adds to their strength, for, according to another theorem, explained by Galileo, two hollow columns of the same quantity of matter, of the same weight and length, bear to each other a proportion of strength measured by the diameter of their internal excavations.

The breadth of surface of the articulations of the inferior extremities, assists, materially, in giving them additional strength, when, in standing, these bones are in a vertical direction. No articulation has a broader surface than that of the thigh with the leg and knee pan. Among the orbicular articulations, no one has more points of contact than the joint of the thigh bone to those of the pelvis. Professor Barthez says, that when the body is erect, the head of the thigh bone and the acetabulum of the os innominatum, which receives that bone, come in contact in a surface of small extent. I am, on the contrary, of opinion that in no possible case can the contact of two bones be more complete. The middle line of direction of the upper part of the thigh bone, is then exactly perpendicular to the surface of the condyloid cavity, which embraces and touches, in nearly every point, the almost spherical head of that bone.

The cervix on which the head of the bone is placed, by keeping the thigh bone at a distance from the cavity of the pelvis, increases the extent of the space, in which the centre of gravity may vary without being carried beyond its limits.

CLXXXIII. The erect posture does not imply a perfect absence of motion. It is, on the contrary, accompanied by a staggering which is the more marked in proportion as the person has less strength and vigour. These perpetual oscillations, though but slightly distinct, in a man who stands upright, depend on the incapacity of the extensors to keep up a constant state of contraction, so that they become relaxed for a short time, and the intervals of rest in the extensors are frequent, in proportion to the weaker state of the subject.

Some physiologists have given a very inaccurate idea of standing, by making that attitude depend an a general effort of the muscles; the extensors only, are truly active. The flexors, far from assisting, tend, on the contrary, to disturb the relation between the bones, necessary to render that state permanent. This explains, why standing is so much more fatiguing than walking, in which, the extensors and flexors of the limbs, are in alternate action and rest.

It may be said, nevertheless, that to give the greater firmness to the attitude, we sometimes contract, in a moderate degree, the flexors themselves; then, that great part of the real force of the muscles, which acts according to the direction of the levers which they are to set in motion (CLXV.) and which is completely lost in the different motions which they produce, is usefully employed in drawing together the articular extremities, in keeping their surfaces firmly applied to each other, and in maintaining their exact superposition which is necessary to the erect posture of the body. No one that I know of, had taken notice of this employment of the greater portion of our muscular power, which was thought completely lost by the unfavourable arrangement of our organs of motion. The line, according to which all the parts of the body bear on the plane which supports them, has much more tendency to fall forwards than backwards;* and falls forward are the most common and the easiest. Thus, nature has directed, in the same direction, the motion of the hands, which we carry forward to break the force of our falls, to prevent too violent shocks, and to lessen their effect. At the same time, she has provided means of protection towards the sides which the hands could not guard. She has given more thickness to the back part of the skull; the skin which covers the neck and back, is much denser than that which covers the fore part of the body. The scapula, in addition to the ribs, protects the posterior part of the chest. The spinal column lies along the whole length of the back; the bones of the pelvis have their whole breadth turned backward.

Falls are the more serious, as they occur in a more perfect state of extension of the articulations; the falls of a child whose limbs are in an habitual state of flexion, are much less dangerous than those of a strong and powerful adult, whose body falls in one piece, if I may be allowed that expression. The falls which skaiters meet with, on the ice, are often fatal from fracture of the skull which placed at the extremity of a long lever formed by the whole body, whose articulations are on the stretch, strikes the slippery and solid ice, with a momentum increased by the quickness of the fall.

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* This tendency is much less distinct in tall slender men. It is observed, that they, for the most part, stoop in walking, less from the habit of bending forward, than to prevent the centre of gravity from falling behind. Pregnant women, dropsical patients, all persons who have much embonpoint, throw their body back, from an opposite and easy understood reason.

We have already seen, that wading fowls remain a long while standing, without effort, by means of a peculiar contrivance in the articulation of the tibia to the thigh bone, but all other birds, are obliged to employ muscular action when standing, except during sleep. The greater part, it is well known, roost on a branch which they grasp firmly with their claws. Now, this constriction, by which they cling to their support, is a necessary result of the manner in which the tendons of the flexors of their feet descend along their legs.—These tendons pass behind the articulation of the heel; a muscle which arises from the pubis joins them, as it passes in front of the knee, so that the bird has but to give way to his weight, and the joints, becoming salient on the side along which the tendons run, stretch and pull them, and make them act upon the feet, so as to draw in the claws to clasp tightly the branch on which he is perched, Borelli was the first who understood distinctly and explained satisfactorily this phenomenon*.

CLXXXIV. Although standing on both feet is most natural to man, he is able to stand on one; but the posture is fatiguing, from the forced inclination of the body to the side of the leg which supports him, and the effort of contraction required to keep up this lateral inflexion. The difficulty increases if, instead of resting on the entire sole, we chuse to stand on the heel or on the toe: the base of support is then so small, that no effort is sufficient to keep the centre of gravity, long together, in the requisite situation.

As to the degree of separation of the feet, which gives the firmest possible stand, it depends upon their length. When they enclose a perfect square, that is, when, taking their length at nine inches, each side of the quadrilateral figure is of that measure, the stand is the firmest that can be conceived. Nevertheless, we are far from keeping or taking this posture to prevent falls. The wrestler, who wants to throw his antagonist, strides much more; but then, he loses on one side what he gains on another; and if he stride 36 inches, on the transversal line, it will need much greater force to overthrow him on that side; but it will take much less to throw him forwards, or on his back. Wherefore, one of the great principles of this gymnastic art, is to bring back the feet to a moderate stride, in the line of the effort which is foreseen to require resistance.

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* *De motu animalium*, Prop. 150. *Quæritur quarè aves stando, ramis arborum comprehensis, quiescunt et dormiunt absque ruinâ.* Tab. II. fig. 7.

There is some resemblance to standing, in the attitudes of kneeling and sitting.

In the first, the weight of the body bears upon the knees, and we must bring back the body, to throw the centre of gravity over the middle of the legs. Accordingly, if we have nothing before us to lean on, this posture is extremely distressing, and we cannot long keep it on. I have said, in another work, that genuflexion rendered monks very liable to hernia; the abdominal viscera being pushed against the anterior and lower part of the abdomen, by the throwing back of the body.

In sitting, the weight of the body bearing on the tuberosities of the ischia, there is much less effort required than in standing on the feet. The base of support is much larger; and when the back leans, almost all the extensor muscles employed in standing, are in action.

CLXXXV. *Of the recumbent posture. Decubitus.* All the authors who, like Borelli, have treated professedly of the animal mechanism; all the physiologists, who, like Haller, have set forth, in some detail, the mechanism of standing, and of progression, have completely passed over the consideration of the human body in repose, left to its own weight, in lying on an horizontal plane. The intention of the following observations is to fill up this gap. Let us consider, at setting out, that lying on an horizontal plane, is the only posture in which all the locomotive muscles recover the principle of their contractility, exhausted by exertion. Standing without motion, has only the appearance of repose, and the unremitted contractions it requires, fatigue the muscular organs, more than the alternate contractions, by which the various motions of progression are carried into effect.

The human body, stretched on an horizontal plane, reposes in four positions; as it lies on the back, the belly, or one or other of the sides. The Latin tongue expresses the first two situations, by the terms supine and prone. It has no particular word for lying upon the side.

Lying upon the right side is the most ordinary posture of sleep, in which we rest most pleasantly, and longest together. There are very few, except under constraint of some faulty organization, who lie on the other side. This depends on two causes; when the body lies on the left side, the liver, a bulky viscus, very heavy, and ill steadied in the right hypochondrium, presses with all its weight on the stomach, and draws down the diaphragm: thence ensues an uneasiness, which hinders long continuance of sleep, or disturbs it with distressing dreams: then the human stomach presents a canal in which the course of its contents is obliquely directed from above downwards, and from left to right: the right or pyloric orifice of the stomach is much less raised than its left or cardiac orifice; lying on the right side favours, therefore, the descent of aliments, which, to pass into the intestines, are not obliged to ascend against their own weight, as they must, in lying on the left side. These two anatomical causes exert their influence on the generality of men, and if there are any who fall into the habit of lying on the left, one may safely conjecture some vicious organization, or some accidental cause, that determines them, as by instinct, to this posture.

Let us suppose an effusion of blood, water, or pus in the sac of the pleura of the right side. The patient lies on this side, that the weight of his body may not oppose the dilatation of the sound side of the chest. The parietes of this cavity are not equally distant from its axis; the pressure of the body on the plane of support, prevents the separation of the ribs, whether as a mechanical hindrance to the displacement of these bones, or in numbing the contractility of the muscles of inspiration, all more or less compressed: Now, as the healthy lung must supply the place of the diseased, nothing could be more in the way than to produce, on that side, by a bad posture, a constraint equal to that occasioned by disease, on the other.

It has long been imagined, and it is taught still, that, in thoracic effusions, patients lie on the side of the effusion, to hinder the effused fluid from pressing on the mediastinum, and pushing it against the opposite lung, of which it will constrain the developement. The following experiments shew clearly enough the error of such a supposition:

I have several times produced artificial hydrothorax, by injecting, with water, the chest of several bodies, through a wound in one of the sides. This experiment can be made, only on bodies in which the lungs are free from adhesion to the parietes of the chest, and the number is smaller than might be imagined; you may introduce in this way from three to four pints of water. I afterwards opened carefully the opposite side of the chest: the ribs removed and the lung displaced, gave room to see distinctly the septum of the mediastinum stretched from the vertebral column to the sternum, and supporting, without yielding, the weight of the liquid, whatever might be the posture given to the body.

It is for the sake then, evidently, of not preventing the dilatation of the sound part of the respiratory apparatus, already condemned in one part to inaction, that patients, in thoracic effusion, lie constantly on the side of the effusion. It is for the same motive, to which we may add that of not increasing the pain by dragging downward the inflamed pleura, that patients in pleurisy lie on the affected side. The same thing happens in peripneumonies; in a word, in all diseased affections of the lungs and parietes of the chest.

Lying on the back, which is unusual in health, is natural in many diseases. It commonly indicates more or less weakness of the muscles of inspiration. The contractile powers which perform the dilatation of the chest, when affected with adynamia, in fevers of a bad character, or after extreme fatigue, carry very imperfectly into effect this dilatation. Nevertheless, a determinate quantity of atmospherical air, must be admitted, every moment, into the lungs, and the general weakness would be increased, if respiration did not impregnate the blood with a sufficiency of oxygen: patients choose, therefore, the posture which makes the dilatation of the lungs easiest for their weakened muscles. The posterior paries of the chest on which the body reposes, in lying upon the back, is almost useless in the expansion of the cavity. The ribs, which have the centre of their motions in their articulation with the vertebral column, are almost immoveable backwards, and the moveableness of these bones, increases with the length of the lever which they represent. So that, no where is it greater than at the anterior extremity terminating in the sternum. Thus, lying on the back has the double advantage of not constraining any of the muscles of inspiration, and of not opposing the motion of the ribs, except at that part where these bones have the least play: lying on the back is one of the characteristic symptoms of putrid or adynamic fever, of scurvy, and of all the diseases of which debility of the contractile parts, forms the principal characteristic. After the fatigue of a long march, or of any other continued exertion, we take this position in lying, and change it, only when sleep has sufficiently replaced the loss of contractility.

Lying on the belly has effects directly the reverse. The expansion of the chest is hindered, exactly where the bony structure is formed for the greatest play of motion: the abdominal viscera are besides pushed up on the diaphragm, of which they resist the depression, and the posture is accordingly unusual. The continuance of it during sleep is possible only to the robust: others, even when they do fall asleep in this posture, soon wake from troubled and distressing dreams, under the agony known by the name of the night-mare. We sometimes seek this posture to constrain respiration, and so abate inward excitation, in the ardour, for instance, of a febrile paroxysm.

The different postures of lying having reference to the degrees of facility of respiration, very young children and persons advanced in years, prefer lying on the back, this posture being, as was already observed, the most favourable to the motions of respiration. Respiration, like all the other functions of the animal economy, with the exception of the circulation and of the phenomena which immediately depend on it, requires a kind of cultivation; it is but feebly performed at an early period of life. It is only after a certain number of years, and when the muscles of respiration, at first small and weak, acquire strength from the very circumstance of being called into frequent action, that the chest dilates with facility, and that the lungs enjoy the full exercise of their faculties. Until that period, the enlargement of the chest and the dilatation of the lungs took place, in an imperfect manner, the child was unable, even by spitting, to free itself of the mucus with which its bronchiæ are apt to get filled, and which render the pulmonary catarrh, called the hooping cough, so dangerous at an early period of life. In like manner, in an old man, the muscles, debilitated, and returned to the relative weakness of infancy, in vain strive to clear the air cells of the mucus with which they become obstructed in the suffocating catarrh. The mechanical process of respiration is, therefore, equally difficult in the child, from the weakness of the muscles which have remained in a long continued state of inactivity; in the old man, from the debility of the same organs and from the induration of the cartilages. Thus, at those two distant periods of life, it is most natural to lie on one's back, but there is a sufficiently remarkable difference in that respect, and which may now be inquired into.

In the foregoing observations, I have always spoken of the human body as stretched on a perfectly horizontal plane. It is seldom, however, that we rest on such a surface; almost every one, and especially persons advanced in life, require that the plane should be inclined, and that the head should be raised, to a certain degree, else the brain would become affected with a fatal congestion of blood. Children, on the other hand, suffer no inconvenience from a neglect of this precaution, whether it is that, in them, the vital power has more energy, and thus balances better the laws of mechanics, by opposing more powerfully the effects of gravitation, or whether it is, that in very young children, the parietes of the arteries within the skull, have a proportionate thickness, and consequently greater power. The extreme disproportion observable in adults, in the thickness of the parietes, between the cerebral arteries and those of other parts of the body, is but trifling in children; and may not this difference of structure, which I have several times observed in the course of dissection, be considered as one of the principal causes which, in old age, bring on apoplexy, a disease to which the child is not liable.

It is well known, that as the enlargement of the chest is produced by the depression of the diaphragm, persons who have taken a plentiful meal, dropsical patients, pregnant women, cannot rest, without lying on a very inclined plane, so that the chest being considerably raised and the patient, as it were, seated, the weight of the abdominal viscera draws them towards the most depending part, that their bulk may not interfere with the depression of the diaphragm.

We might now inquire what is the posture in which the body rests with least fatigue; this investigation, unimportant to the physician, would be of the highest value to the arts which have for their object the imitation of Nature. In consequence of ignorance on this subject, we often see, in the works of several of our sculptors, figures in attitudes of repose so incorrect and uneasy, that they could not maintain them, without considerable effort and fatigue.

CLXXXVI. *Of the motions of progression. Of walking.* Walking, running, and leaping, are so closely connected, that it is difficult to distinguish them. There is, in fact, very little difference between walking, in a certain manner, or running; and running is most frequently produced, by the complicated mechanism of running and leaping. In the most natural way of walking, we, in the first instance, poize the body on one foot, then, bending the opposite foot on the leg, the latter on the thigh, and the thigh on the pelvis, we shorten that extremity; we, at the same time, carry it forward, extend its articulations which were bent, and when firmly applied to the ground, we bend the body forward, and carry back the centre of gravity in that direction; and performing the same motions with the limb which remained behind; we measure the space the more rapidly, cæteris paribus, as the levers on which the centre of gravity alternately bears, are longer. The weight of the body, compared to that of the lower extremities, is as that of a carriage which moves, in succession, on the different spokes of its wheels.

The centre of gravity does not move along a straight line, but between two parallels, in which space it describes oblique lines from the one parallel to the other, and forms *zig zags*. The oblique direction of the neck of the thigh bones, accounts for the lateral oscillations of the body, when we walk; the arms which move, in a different direction, from that of the lower extremities, serve to balance us, preserve the equilibrium, and correct the staggering which would be much greater, if the neck of the thigh bone, instead of being oblique, had been horizontal. The impulses communicated to the trunk, are reciprocally balanced, and the latter moves in the diagonal of a parallelogram, whose sides are represented by the line of these impulses. We constantly deviate from the straight line, in walking, and if the sight did not enable us to see, at a distance, the object towards which we are moving, we should go to a considerable distance from it. If you place a man, with his eyes blind folded, in the middle of a square field, he will, in his attempt to get out, and thinking that he is moving in a straight line, make for one of the corners. It is, almost always, towards the left that we deviate, the right lower extremity, which is the stronger, inclining the body towards the opposite side. Those who are lame depart much more from a straight line, and deviate towards the side of the shorter leg. The motions which they are obliged to use, and which render their gait so remarkable, are occasioned by the necessity of incessant and powerful efforts, to prevent the body from giving way to its own weight, and to the greater power of the sound extremity, which inclines it towards the affected side.

The breadth of the feet, and a moderate separation of these parts, give a much firmer support to the centre of gravity. Thus, in walking on a moving and insecure surface, we hold apart our feet, so as to include a greater base of sustentation. Those who have long been at sea, acquire such a habit of holding their feet asunder, in the way they are obliged to do during the rolling of a ship, that they cannot lose the habit, even when on shore, and are easily recognized by their gait. A sailor is unfit for active service, till he has acquired what is called, by sea-faring people, a seaman's foot, that is, till he is capable of stepping firmly on the deck of a vessel tossed by the tempest.

The gait of a woman, from her having smaller feet, is less firm; but ought we, from that circumstance, to infer, with the most eloquent writer of the eighteenth century, that this diminutive size of the foot, is connected with the necessity of her being overtaken in flight. The concave form of the sole of the feet, by enabling them better to adapt themselves to the unevenness of the soil, concurs in giving a firmer footing in walking, and in other motions of progression. There is, in walking, an intermediate moment, between the beginning and end of a step, during which the centre of gravity is in the air; this lasts from the moment when the centre of gravity is no longer in the foot which remains behind, till it returns into the other foot which is carried forward.

Walking is modified, according as it takes place on an horizontal, or an inclined plane; in the latter case, we ascend or descend, and the exertion is much more fatiguing. To explain the action of ascending, let us suppose a man at the bottom of a flight of stairs, which he wishes to go up; he begins by bending the articulations of the limb which he is desirous of carrying forward; he raises it thus, and shortens it to advance; and when the foot, which is in a state of semi-extension, rests on the ground, he extends the articulations of the other extremity, carries thus the body upward, in a vertical direction, and completes this first step, by contracting the extensors of the leg that were first in action, so that they may bring forward and restore to it the centre of gravity, to which the posterior leg, whose foot is extended, has given a vertical motion of elevation. Hence, in ascending, the calves of the legs and knees, especially the latter, are so much fatigued; for, the effort with which the extensors of the foremost leg, bring back again upon it the centre of gravity, is more powerful than that by which the gemelli and the soleus impart to it, by extending the hindmost foot, a motion of vertical elevation.

To relieve the extensors of the leg, we bend the body forward, as much as possible; we lean back, on the contrary, in descending a flight of stairs, or a rapid slope, in order to slacken the motion, by which the body yielding to its own weight, falls on the leg that is carried forward.

At the moment when the centre of gravity is no longer within the base of sustentation, all the powers unite in action, that it may fall, as little as possible, from a vertical direction. The glutœi steady the pelvis, and straighten the thigh, the lumbar muscles extend the trunk on the pelvis; hence, in going down a slope, the loins get so much fatigued. We are less fatigued in going down hill, when the slope is moderate, than in going up hill; as the force of gravitation, or the weight of the body, assists considerably the descending vertical motion. The motion of walking, when we take very long steps, resembles that of going up hill, as the body being lowered, every time the legs are much apart, requires to be elevated, at each step, towards the foremost leg.

At every step we take, the articulation of the leg with the foot is the principal seat of an effort, to which physiologists have not paid any attention. The whole weight of the body is supported by the action of the levator muscles of the heel, and the astragalus supports this weight, which varies according to the corpulence of the person, and the burthen with which he is loaded. The weight of an adult, of common stature and of moderate size, may be estimated at about 150 pounds; but which sometimes, in corpulent people, amounts to between four and five hundred pounds. If, then, to the weight of the body there be added that of the burthens which it may support, it will be conceived how immense the efforts must be, which are, as it were, unconsciously, carried on, in the articulation of the foot with the leg. But how numerous the resources which nature has provided to overcome this great resistance; how many the circumstances she has happily combined to accomplish this without fatigue! In the first place, the foot in this action, represents a lever of the second class, and this lever, it is well known, is the most advantageous, the resistance being always nearer to the fulcrum than the power, and the arm, by which the latter acts, consisting of the whole length of the lever. If you attend to the mechanism of the different parts of the skeleton, you will no where find so powerful a lever applied in so favourable a manner. The os calcis, by carrying the foot beyond its articulation with the leg, adds likewise to the length of the lever by which the power acts. Its length has considerable influence on our strength, on our power of taking, without fatigue, long walks, or engaging in exertions requiring considerable muscular force in the lower extremities. The negroes, who excel in running, in dancing, and in all gymnastic exercises, have a longer and more projecting heel than Europeans. They dance best, whose tendo Achillis is most detached, that is to say, projecting, and at the greatest distance from the axis of the leg; which implies, that its lower attachment is carried back, by the prolongation of the os calcis.

Those who have a short heel, have a long and flat foot; this conformation, which, when marked, is faulty, is not only unfavourable to beauty of form, but is besides, remarkably injurious to the strength of the limb, as well as to freedom of motion. Men with flat feet, are always bad walkers, hence, this flattened form, when very considerable, is considered as unfitting a man for military service. Lastly, the term denoting this physical imperfection *(pieds plats)*, is accounted insulting in the French language, as well as in several others. But let us go on with our inquiry into the advantageous disposition of the articulation of the foot with the leg, for facility in walking, and in the different motions of progression.

We have seen that the tendons are generally inserted at a very acute angle, into the bones on which they act; in the present instance, however, the insertion takes place at a right angle, the common tendon of the muscles of the calf of the leg joining the os calcis, at the angle most favourable to their freedom of action. With the exception of the muscles which move the head and lower jaw, no others are so evidently disposed with this purpose. Nature has not been contented with forming the foot in such a manner as to afford the most advantageous lever, to which the moving powers are applied, at the greatest possible distance from the fulcrum and at the angle most favourable to their action; she has further, increased the efficacy of this action, by adding extraordinarily to the number of muscular fibres. There is not, in the body, a stronger muscle than the soleus, whose short and oblique fibres between the two wide aponeuroses which cover its anterior and posterior surfaces, are more numerous than in any other muscle, as may be conceived, by considering the extensive surfaces to which they are attached. Besides, the tendo Achillis is kept in a due degree of straightness, by the aponeurosis of the leg behind it.

Every thing, in the powers, as well as in the levers, is formed so as to overcome the resistance, without difficulty; that is, so as to raise the weight of the body, by the extension of the foot, the end of which rests on the ground, in every motion of progression.

This immense power with which the muscles of the calf of the leg act to raise the heel, and to support the whole weight of the body resting on the astragalus, accounts for the possibility of transverse fractures of the os calcis, and for the rupture of the tendo Achillis, notwithstanding its great thickness; and should lead one not to allow patients, after such accidents, to walk freely, for several months; the substance which unites the parts being liable to rupture, as is known to have been the case, in several instances. This same arrangement of parts likewise accounts for an accident, which physiologists have long endeavoured to explain by a very unsatisfactory theory.

It not unfrequently happens, that the mere effort of walking occasions a rupture of some of the fibres of the gemelli and of the soleus, in consequence of which, there comes on pain, attended with induration of the muscles, and with a certain degree of ecchymosis, occasioned by the extravasation of blood. Pathologists suppose these symptoms to depend on a rupture of the plantaris muscle: this rupture, however, is hypothetical, has never been proved by experience to exist, and its supposed symptoms are altogether idle and fallacious.

I could, if it were not out of place, bring forward several cases of this affection; in all the cases which have come under my own observation, the use of the bath, of emollient and slightly narcotic poultices, but above all, continued rest, while the symptoms lasted, have appeared to me the most appropriate remedies.

CLXXXVII. *Of running.* In running, the foot that is hindmost being raised before that which is foremost be firmly applied to the ground, the centre of gravity is, for a moment, suspended, and moves in the air, impelled by the force of projection, the action of which principally constitutes leaping.

The mechanism of running is a compound of that of walking and leaping, but resembling most the latter; hence some authors have defined it to consist of a succession of low leaps. The steps are not longer than in walking, but merely succeed each other with greater velocity. The centre of gravity is transferred, with more rapidity, from one leg to the other, and falls are much more apt to take place. The quick repetition of the same motions, in running, requires a very lively contractility in the muscles which move the extremities, and as the energy of this vital property is proportioned to the extent of respiration, to the quantity of air which the blood acquires in passing through the lungs; in running we pant and breathe frequently, and at short intervals, without any particular enlargement of the chest, at each act of respiration. It was necessary that the parietes of this cavity should, in running, be remarkably fixed; for, it becomes the point on which those muscles are inserted which steady the pelvis and loins, and prevent their yielding an unsteady basis to the lower extremities. The best runners are those who have the strongest lungs, that is, who can give to the chest the greatest degree of permanent dilatation. In contending for the prize in running, you may see them throw back their head and shoulders, not only to obviate the propensity which there is in the line of the centre of gravity to fall towards the anterior plane, but, likewise, that the cervical column, the scapulæ, the clavicles, and the humerus being fixed, may furnish a firm attachment to the auxiliary muscles of respiration.

We should run with much less speed, if we applied to the ground the whole sole of the foot; partly from the time which would be taken up in thus applying the foot to the ground, and partly by the friction which would necessarily take place. Hence, in running, we generally touch the ground, only with the end of the foot. We run with most speed, when the foot is in a state of extension, the leg being moved rapidly by the extensors of the knee. This accounts for the tendency which there is to fall while we run, the centre of gravity obeying impulses which follow each other in rapid succession, and never resting but on a basis of very limited extent. Another reason why the slightest unevenness of the ground is apt to occasion falls in running is, that the rapid motion communicated to the body by the sudden and perpetually recurring extensions of the posterior extremity, increases, at every step, so that it is impossible to stop suddenly, and without having previously slackened one's pace, and moderated the impulse to which the body is subjected.

As it is mostly forward that falls are apt to take place, in running we always throw back the head, and make use of our arms to balance the body, so that they may be in constant opposition to the legs, that is, that the right lower extremity, for example, being carried forward, the left arm may be balanced backward.

Few animals are better formed than man to run with speed, his lower limbs are in length equal to one half of the whole length of the body, and the muscles which move them are very powerful; hence, savages, who are in the constant habit of running, overtake the animals which they make their prey; and, even in Europe, there are professed runners who equal in swiftness the fleetest horse. This animal, like every other swift quadruped, would move much more slowly than man, on account of the number of the limbs on which he rests, if he had not the power of moving them in pairs, and thus reducing his legs to two, as in what is called full gallop.

CLXXXVIII. *Of leaping*. Leaping, in man, is performed, principally by the sudden extension of the lower limbs, whose articulations were in a previous state of flexion. The alternate angles of the foot, of the knee and hip, disappear, and the extensors contract in almost a convulsive manner. This straightening is not limited to the lower limbs, in violent leaping; it, likewise, affects the vertebral column, which acts as a bow in unbending. Professor Barthez, who has the merit of having suggested this explanation, which Borelli and Mayow had very imperfectly understood, perhaps goes too far, in considering as imaginary, a power of repulsion in the ground. This reaction, admitted by Hamberger and by Haller, clearly operates, when we leap on an elastic floor, it enables tumblers to rise, without much effort, on the rope which bears them. But though all physiologists do not admit that, in leaping, there is a re-action from the ground; it is universally admitted, that there must be a certain resistance, from the ground on which we tread. In fact, a moving sand, yielding to the pressure of the body, would, by giving way to a considerable degree, render it impossible to leap. The instantaneous contraction of the extensor muscles is so powerful, in extending the lower extremities, and in communicating to the body a power of projection, so as to raise it, that frequently, during this effort, the tendons of these muscles, or even the bones into which they are inserted, break across. It is on this account, that dancers are very apt to fracture their patella. This accident happens, at the moment when their body, in rising from the ground, is powerfully elevated to a certain height.

If leaping consists merely in the sudden straightening of the lower extremities, whose articulations are bent in alternate directions, it must be more considerable, according as these are longer more bent on one another, and as the muscles which straighte them contract more powerfully. Hence, animals that move b leaps, as the hare, the squirrel, and the jerboa, have posterior extremities of considerable length, in proportion to their fore legs Their different parts are, besides, capable of considerable flexior All these animals, strictly speaking, are incapable of walking c running, and they move by leaps or bounds succeeding each other with different degrees of rapidity. Some, however, as the rabbit and the hare, are capable of running, when climbing up a steep place, as the slope, in this case, lessens the effect of the impulse communicated by the extension of the posterior limbs; an impulse which, from the strength and length of these extremities, throws the whole weight of the body on the fore legs, which are weaker and shorter, with such a degree of force, that the animal is obliged to stiffen these and to keep them straightened, and in a state of extension, to avoid striking the ground with his head, while leaping on an horizontal plane. Frogs, but especially grasshoppers and fleas, between whose hind extremities and the rest of the body, there is the greatest disproportion, astonish us by the very considerable space which they can clear at a leap; but the wonder ceases, when we consider that powers communicate to the masses equal degrees of velocity, when proportionate to one another; now, the space gone over, depending entirely on the velocity, since the body that leaps, loses, by a gradation which nothing can lessen, that which it had acquired; these motions must be, nearly alike, in small and in large animals.

Swammerdam says, that the height to which grasshoppers rise, in leaping, is to the length of their body as 200 to 1. A flea leaps still farther and more swiftly*.

The larva, called the cheese maggot, forms itself into a circle, by contracting, as much as possible, its abdominal muscular fibres; after having, in this manner, brought near to each other its head and tail, it suddenly extends and straightens itself, and sends itself no a considerable distance. It is by a similar mechanism, that the salmon, the trout, and other fishes, swim against rapid currents interrupted by water-falls. They bend their body, to a considerable degree, straighten it powerfully, and thus overcome the obstacle which opposes their progress. I believe, however, that in this particular case, the leap is not effected solely by the straightening of the elastic curve, as is maintained by some authors, but that it is likewise occasioned by the resistance against the water, of the tail of the fish, which strikes it powerfully, at the moment of raising itself; in the same manner, as in the northern seas, the enormous whale strikes, with so sudden and violent a blow of her tail against the water, as to receive from it a fixed point, and rise to the hight of fifteen or twenty feet, as we are informed by navigators.—Lobsters leap, by violently extending their tail, an elastic and contractile arch, which they had previously kept bent under their body.

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* Barthez states, in his work on mechanics, that the Arabs call this little insect the father of leaping; and that Roberval, a natural philosopher of considerable merit, had written a work entitled *de saltu pulicis*. Such a subject, thought by the ignorant to supply matter only for idle and fruitless speculation, may furnish results highly interesting, when treated by an able man. *In tenui labor.*

This theory of leaping would seem to be contradicted by what is related by Professor Dumas, of a man without thighs, and who, nevertheless, performed surprising feats of dexterity and agility. But in this instance, might not the pelvis, the vertebral column, and especially the lumbar portion of the latter, make up, by a greater mobility, for the want of the longest of the three levers formed by the lower extremity.

In the act of leaping, the body, which has received the impulse, may rise in one of two ways, perpendicularly to the horizon, which constitutes the vertical leap, or in a direction more or less oblique. The vertical leap is always of less extent than that which takes place in an inclined direction, and the latter is always greater, when it has been preceded by running. In running before leaping, we have already acquired an impulse which is added to that which the mechanism of leaping may produce.

To convince ourselves of the reality of this additional power, let us recollect how difficult it is to stop suddenly, in the midst of a race, if we have not previously slacked our pace. This impulse is one of the causes which make runners fall forward, when the slightest obstacle meets their feet; but whatever may be the force, the direction of leaping, and the powers which produce it, the body by which it is executed must be considered as a real projectile that is impelled, by a motion counteracted by the force of gravitation. Whatever motions we may perform, every thing depends on the first impulse; as soon as the feet cease to be in contact with the plane which supports them, it is no longer in our power, to augment the force of the leap or its swiftness. In dancing, it is impossible to excel in cutting capers, unless one is capable of rising to a certain height; I have uniformly observed, that in the most celebrated public dancers, the trunk, and especially the lower limbs, are very muscular, the calf of the leg, the buttocks, and the back indicate, by their bulk, a remarkable degree of energy in the extensors, by whose action, leaping is chiefly effected.

A dancer who rises vertically, falls back to the ground, when the force of gravitation exceeds the impulse which he had received; his fall resembles that of a projectile in vertical motion; it takes place, according to a descending line that is perfectly similar, in direction and height, to the ascending line.

The same thing takes place in the oblique leap, except however, that the body, like a shell projected by the explosion of gunpowder, describes a parabolic curve, ascending, as long the impelling power exceeds the force of gravitation; descending, when the latter, which increases during the progress of the leap, is equal to the force of impulse. This takes place, when the body has described a curve which represents the half of a parabola; from that moment, the force of gravitation goes on increasing, and the body descends in a curve corresponding to the first*.

CLXXXIX. *Of swimming.* Few animals have more difficulty than man, in supporting themselves on the surface of a fluid; yet the weight of the human body exceeds but little that of the same bulk of water; sometimes even, when the body is loaded with much fat, its specific gravity and that of water are the same. Hence, it is observed, that corpulent men swim with less effort; but the weight is not equally distributed over every point of the supporting fluid. The head, whose relative weight is very considerable, is the principal difficulty in swimming, and it requires some effort to keep it raised, so as to allow the air to enter freely into the lungs, through the mouth and nostrils. The upper and lower limbs act alternately against the water which they displace by pressing on it. In these various motions, there is a successive flexion, extension, abduction, and adduction of the limbs; most of the muscles of the body are in motion, and have their fixed point of action in the chest, which swimmers keep expanded by retaining, by a constriction of the glottis, a considerable quantity of air within the pulmonary tissue. This continuous dilatation of the chest is attended with this further advantage, that it renders the body specifically lighter. The force with which the swimmer is obliged to strike the water, the rapidity with which the motions must succeed each other, that the fluid may yield him a sufficiently fixed point of action, accounts for the fatigue with which this exertion is attended.

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* *In saltu ad horizontem obliquo, motus fit per lineam parabolicam proximè*—Borelli. op. cit. prop. 178. Vide Galileo on the motion of projectiles.

Fishes are adapted, by their structure, to the element in which they live—the form of their body bounded, every where, by salient angles, is well calculated to separate the columns of a fluid. A bladder filled with azote, which is expelled at pleasure, renders their specific gravity less than that of water, according to the quantity of gas it contains; lastly, their tail, moved by powerful muscles, may be considered as an oar of great strength, the motions of which impel the fish forward, while the fins, like so many secondary oars, facilitate and direct his motions.

The air bladder of fishes gives to their back a sufficient degree of lightness to enable it to remain upward, else this part of the body, which is the heaviest, would draw after it the rest, and the animal, lying on his back, would be incapable of performing any motions of progression; this happens when this bladder is burst or punctured. Constrictor muscles expel the gas which it contains, and force it into the stomach, or œsophagus, when the animal wishes to sink. This expulsion becomes impracticable, if the gas undergoes considerable expansion, from the application of heat, and resists the compression that is applied to it. Hence, during the fry-time, fishes, after remaining long, on the surface of the water, exposed to the heat of the sun, become unable to sink, and are easily caught.

As the fish is entirely surrounded by a medium which presents, on every side, an equal resistance, the velocity which he might have acquired, by striking the fluid behind, with his tail, would be lost, from the resistance of the water which he would have to displace forward, if, immediately after striking with his tail, he did not bring it back into a straight line, so as to present to the fluid, only the inconsiderable breadth of his body; the velocity with which he moves is, besides, very inferior to that with which he uses his tail.. This part being brought into a straight line, the fish contracts it to its smallest dimensions, at the same time that he brings it to the other side; he then expands it and strikes the fluid, in a contrary direction, in a line between the two oblique impulses which both strokes have given to it. The fish turns horizontally, and directs himself towards the side he chooses, by striking more powerfully, or with greater quickness, on one side than on the other, or by striking only on one side.

Fishes without an air bladder, are reduced to live at the bottom of the water, unless they have a flat body and are furnished with horizontal fins, so as to enable them to strike a considerable surface of water, in a powerful manner, as is the case with rays, whose wide fins are not inaptly termed wings, the motion of these fishes, in the water, precisely resembling that of birds in the air, with no other difference but that of the different density of the medium in which they move, as will be shewn in treating of the motions of progression peculiar to this class of animals.

CXC. *Of flying.* A bird, in rising, or in moving in the air, has to use much more force and with much greater velocity, than a fish in swimming. He has not the power, like the latter, of placing himself in equilibrio with the fluid in which he moves, by means of an internal organ that renders his specific gravity equal to that of the medium he is in. This medium, besides, presents less resistance to the powers which strike it to obtain a point of support.

Though birds are incapable of becoming as light as the air, it is, however, in their power to obtain a specific gravity, not much exceeding that of the atmosphere. Nature has rendered them very light, by providing them with very capacious lungs, capable of great dilatation, from the remarkable mobility of the parietes of the chest, and by extending the lungs into the abdomen, by means of membranous sacs, and into the skeleton, by means of canals which establish a communication of these abdominal and osseous aerial tubes with the pulmonary organ; so that the whole body, distended by air rarefied by a considerable degree of heat, since it is ten degrees above that of other warm-blooded animals, clothed in feathers almost as light as the air itself, requires but a moderate degree of force to support itself in that medium. On the other hand, when the wings are expanded, they present to the fluid a very extensive surface; the pectoral muscles which set them in motion, are besides, sufficiently strong to strike the air with a power, and to repeat the stroke with a rapidity and continuousness of which no other animal would be capable. We know how powerful* the muscles of the wings are, even in the tame fowl, which make so very little use of them. Lastly, the contractility of these very powerful muscles, is greater in birds than in any other animal, no one possesses so much strength in so small a compass. What quadruped of the same weight as an eagle, could strike with his foot so violent a blow as that bird, when to stun his prey or to defend himself, he gives repeated blows with his pinion? This muscular energy is, no doubt, connected with the extensive respiratory organs, with the highly stimulating qualities of a blood that is warmer, more oxidized, more concrescible, in a word, more arterialized, than that of any other animal.

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* Birds have three pectoral muscles; the *great pectoral* which is attached to their enormous sternum, and alone exceeds in weight all the other muscles of the bird together; the *middle pectoral*, whose tendon turns over a kind of pulley, and is attached to the head of the humerus which it raises; by means of this mechanism, Nature has placed an elevator muscle at the lower part of the body, so as to increase the weight of this part of the bird, which, without this kind of ballast might have been upset in the air. The third, or *lesser pectoral*, is destined to draw the humerus towards the body.

Let us now inquire how birds, endowed with an organization so favourable to flying, perform that action. A bird begins by ascending into the air, either by rising at once from the ground, or by allowing himself to fall from a height. If, on the ground, and if his wings are too large to be freely spread he has a difficulty in rising; in that case he goes to an elevated spot and throws himself from it, that he may have sufficient room to extend his wings and strike, in the air, the first stroke that is to raise him. The wings expand horizontally, the humerus which forms their principal part, standing off from the body; they then descend rapidly, and, as the air resists the sudden effort which tends to depress it, the body of the bird is elevated by a kind of elastic re-action, corresponding to the leap of man and to the swimming of fishes; the impulse being given, the bird closes his wings, contracts his dimensions, as much as possible, that the impulse may be almost entirely employed in raising his body, and may not be counteracted by the resistance of the air. This resistance of the air, but particularly the weight of the bird, would soon overcome the velocity that has been obtained, and he would drop, if, by again striking the air, he did not again rise. If the bird strikes a second time with his wings, before the impulse communicated by the first stroke is over, he rises rapidly, but, on the contrary, descends, if this motion is delayed. If he allow himself to fall only to the height whence he began to rise, he may, by a continuance of equal vibrations, keep at the same height. A bird, sometimes, ceases altogether to move his wings, closes them against his sides and falls, with a precipitate motion, like any other weighty body. The name of pouncing is given to the rapid descent of predaceous birds on their prey. Observe a falcon drop suddenly on a poultry yard; if on the point of reaching the ground, he perceive danger, he immediately spreads his wings, and thus saves himself from falling; for, whatever velocity he may have acquired in this rapid motion, the resistance of the air always increases, as the squares of the velocity; he then rises anew and takes to flight. This peculiar act is called *resource.*

The oblique motions differ from the vertical motion which has just been described, in this, that the bird rises by a series of curves which are more or less extended, as the motion is more horizontal or vertical. In consequence of the peculiar strength of their wings, birds of prey have a very powerful horizontal motion, so that in soaring, the curves which they describe are so slight, that the motion seems quite horizontal.

Swimming, to many birds, is a more natural mode of progression, than flying; these birds are very light, their body is covered with a light down, and with feathers over which the water glides very readily; their body is flattened and rests on the fluid, by a broad surface. Their pelvis is shaped like the keel of a ship; lastly, their toes united by webs, strike the water with a very broad surface. This is the case with the numerous tribes of web-footed or water-fowl.

They who have conceived it to be possible for man to support himself in the air, by rendering his body specifically lighter, have not considered, that it was imposible to give to the muscles which move the arms, a sufficient degree of strength, to enable them to move the machines which are adapted to them; and all who have ventured to try such machines, have suffered for their rashness.

CXCI. *Of crawling.* All the motions of progression, of which man and animals are capable, may be referred to the theory of the lever of the third kind. The body, in leaping, as in walking, may be compared to an elastic curve, since the point of support, or fulcrum, is in the ground; the force, the spring or power, in the extensor muscles, and the resistance in the weight of the body. What is running, but a succession of short leaps, and is not its mechanism intermediate between walking and leaping? Are not flying and swimming real leaps, in which the body of the animal alternately bends and unbends, having its support on media of much less resistance than the ground, on which walking, running, and leaping are, generally, performed? The mode of progression peculiar to serpents and soft reptiles, furnishes an additional application of the lever of the theory of the third kind. The snake which moves, by forming with its body horizontal and vertical undulations, forms, in the course of its length, a series of curves and straight lines, in succession, from the head towards the tail; but sometimes, likewise, from the tail towards the head, in the serpents called *amphisbænous*, in which the scales covering the belly are equally favourable to a retrogade motion, as to a motion forward.

The crawling of serpents is facilitated by the length of their body, by the smoothness of their scales, the immense power of their muscles, and the flexibility of their vertebral column. The bones which form this part of the skeleton, are articulated by arthrodia, and loosely jointed, so that a very slight cause destroys their union; hence, a blow with a very small stick is capable of killing the largest serpents, if applied on the back. The lateral inflexions, of this column are very considerable; the degree of extension is limited by the spinous processes, and these are, sometimes, of considerable size, as in the rattle snake. Hence, notwithstanding what has been stated by several authors, and although painters have represented serpents moving in vertical curves; they move, in most instances, in horizontal curves.

A serpent, to swim, is obliged to bend and unbend his body, in more rapid succession; this swimming consists merely in crawling faster, and in moving on a less resisting plane.

The motions of reptiles, in swimming, surpass, in strength and velocity, those of reptiles which crawl on the ground, in as much as the latter yields a more fixed point than water. If the serpent is desirous of leaping, he suddenly, and at once, brings to a straight line all his curves, resting, at the same time, on the extremity of that which his nearest his tail; then, as I have several times observed, he describes the smallest possible number of curves, bends into three or four greater arches than usual, but never into a single one, whatever the length of his body may be.

Tortoises, frogs, lizards, salamanders, and all reptiles that have legs, drag themselves along on their belly, being ill supported by their weak limbs, which bear no proportion to the bulk of their body, and can scarcely be said to crawl by a mechanism similar to that which has just been explained.

Caterpillars and maggots crawl much in the same manner as serpents. The legs of the caterpillar, too feeble to support it, or, of themselves, to carry the body forward, are used by these creatures, to obtain a hold on the surface on which they move, by bending, in arches, mostly vertical, the parts situated between the legs, that are in pairs, at a certain distance from one another. The caterpillars that have a scaly covering, crawl better, the elasticity of their scales assisting the contractile action of their muscular fibres. Earth worms move, at times, in undulations, as the snake, and at others, by dragging themselves like slugs. This last variety of crawling is performed as follows: instead of forming distinct curves, the contractile fibres of the reptile, shorten themselves, from the head, which is fixed, towards the tail which is moveable, and the animal performs only slight inflexions. We may compare the mode of crawling peculiar to some animals, to the motion by which a man lying horizontally, on his belly, moves forward, by drawing his whole body towards his arms, which are in a state of extension, and with which he has a hold of some fixed object. The motion of the snail is performed almost entirely in the same manner.

The snail, loaded with his shell, adheres to the surface on which he moves, by a viscid and glutinous fluid which coagulates and forms on his track, a shining varnish. This creature fixes itself, likewise, on the ground, by forming a vacuum with the part of its body on which it crawls, which is broad, fringed and well adapted to answer the purpose of a cupping glass. It is by this double resource of a viscid and glutinous fluid, and of a contractile exhauster, that the snail fixes the fore part of his body, and then draws towards this fixed part, the rest of his body loaded with the shell. This part of the snail, by which it fastens itself to the ground on which it crawls, bears some analogy to the tentacula which assist the progression of the sepia and other cephalopodous molusca.

CXCII. *Partial motions performed by the upper extremities.* These motions will furnish us additional illustrations of the elastic curve, or of the third lever, to the theory of which, may be referred almost all the motions of man and of the lower animals. This idea simplifies and facilitates, in a remarkable manner, the study of animal mechanics; it may be considered as a general formula, by the help of which we may obtain a solution of all the problems of this interesting part of physical science. Its application particularly distinguishes what has just been stated on motion, from what had been, heretofore, written on the same subject.

The upper extremities, in man, are not employed in motions of progression, at least, not generally, except in a few instances, as, for example, when the limbs being extended and the hands having a firm hold of a body, the action of the great pectorals draws the whole body, lying prone on a horizontal surface, or suspended.

We experience a difficulty in climbing, because our hands alone enable us to grasp the body on which this mode of progression is to be effected, while the four extremities of the quadrumana and the sharp claws of cats, those of climbing birds, render this action easy and natural to all these animals.

There exists so great a disproportion, in point of length and strength, between our upper and lower extremities, that walking on all fours can never be natural to the human species; besides, as Daubenton observed, the situation of the foramen magnum of the occipital bone, in man, renders this attitude exceedingly uneasy. Its situation, near the centre of the base of the skull, and nearly horizontal, prevents the head from being raised sufficiently high to enable us to turn our face forward and to see before us, and if we bring the head downward, it strikes the ground with its summit, or with the forehead*. But our upper or thoracic limbs, though of no use in conveying us whither our wants require, are almost exclusively destined to perform motions by which we act on the objects towards which we have brought ourselves.

If we wish to push, or to draw towards us, or to propel afar a moveable body, to compress, to elevate, or to lower it, our upper extremities are almost exclusively engaged in this office.

In *pushing*, man places himself between the obstacle and the ground; he bends his body between these two points, by bringing all his limbs into a state of flexion; he then extends them; his whole body represents a spring which is released and recovers itself, and the two extremities of which, meeting two obstacles, the ground, and the body to which the impulse is to be communicated, exert their action on the one of the two which is the more easily moved. The force is equal to the contraction of the extensors, which elongate the body previously in a state of decurtation, and advance the moveable obstacle by the whole difference, in regard to length, of a man, whose limbs are in a state of flexion, and of the same man while these parts are in a state of extension. It is, in the same manner, and by a similar mechanism, that by pushing against the shore, with an oar, we force a boat from it. The vertebral column represents an elastic curve which straightens itself, between the feet which rest against the bottom of the boat and the end of the pole or oar, pushed against the shore, or the bottom of the water.

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* Dictionniare d'Histoire naturelle de l'Encyclopédie méthodique. Introduction, page 21 et suiv.

If, on the contrary, we wish to draw towards us a body, we seize it with extended arms, we then bend them forcibly; the spring, which is in a state of tension, shortens itself, the effort is wholly performed by the flexors; it is less fixed, and of less duration than that of the extensors, because the axes of the bones do not correspond to one another, in a straight line, and because the action is generally partial.

We can throw, to a distance, a projectile, the arm remaining pendulous and performing a mere oscillatory motion, or by a whirling motion of the arm. This last action is much more powerful, because the muscles which go from the trunk to the upper extremity, concur in it. In the former, the previous oscillations give to the arm a motion which is peculiar to it, which is added to the force of muscular contraction, and which augments its effects.

Professor Barthez was aware, that the motions, by which the upper extremity stiffens itself, and assumes a state of extension to project a moveable body, or to repel a resistance that is opposed to it, perfectly resemble leaping, and are attended, like that action, with a sudden extension of the joints which were previously bent. In motions applied to a resistance that cannot be overcome, the body is not repelled with the force communicated to it in leaping, by the abrupt extension of the lower extremities. The scapula is too moveable on the trunk, its articulation with the humerus is too unsteady, and the action of this bone is not directed, with regard to the shoulder, in a sufficiently favourable manner, to render the impulse equally great, even though the powers should be equal, and they are far from being so. In every repulsion, and in every attraction, whether we bring towards us an object or remove it from us, by acting upon it, with our superior extremities, these limbs represent an elastic arch, which is curved or straightened by the action of its flexors or extensors, and these motions, like the greater number of those which we have hitherto considered, present a precise application of the levers of the third kind.

The action of seizing a body, with the hand, is facilitated, 1st, by the action of the radius on the ulna, which performs pronation and supination, motions which belong exclusively to the hands, and of which the feet are incapable; 2dly, by the mobility of the wrist, which, properly speaking, is capable of flexion and extension in two directions; for, the extension of the hand does not consist in merely bringing it into a parallel line with the axis of the limb, but it is, besides, capable of turning it round towards the back part of the fore arm, a phenomenon not observable in any other articulation; 3dly, by the obscure motions, on one another, of the bones of the carpus, by which the palm of the hand becomes more concave; 4thly, by the motions of opposition and circumduction of the thumb and little finger; 5thly, by the great number of the phalanges; every thing, in this part of the upper extremity, proves the excellence of its structure, and justifies all that philosophers and naturalists have said of its advantages.

In applying pressure, for instance, in pressing on a seal, nearly the whole weight of the body bears on one of the upper extremities which is powerfully extended, the shoulder resting on the arm, so that the glenoid cavity of the scapula may be perpendicular to the head of the humerus.

It would be a superfluous task to endeavour to describe all the motions which our parts may execute; these partial motions are explained in anatomical works, in treating of the muscles on whose action they depend. I shall content myself with having inquired into the principal phenomena of animal mechanism, chiefly with a reference to the human structure. Fuller details, on animal mechanism, would be out of place, in a work like this. They will be found in those works which treat professedly* of this important part of physiology, the only one in which it is possible to obtain, in the investigation of its objects, that degree of mathematical certainty, so much sought after by every man of precision and of sound judgement.

CXCIII. *Partial motions* may yet further be studied as signs expressive of ideas. They compose what is called the language of action; and are supplemental to speech. The language of gestures, in its perfection, is found sufficient even to express the most subtle ideas, and the finest feelings, in the mute scenes, known under the name of pantomimes. The gestures, with which the man of most phlegm accompanies his discourse, are a language superadded to that which he speaks: they contribute to the exposition of the thought:—but what force, in the man of passion, do they not add to his expression! what power to his language! This eloquence of gesture, which was so often employed to move and sway the assembled multitude in the public place of Rome and Athens, was habitual to the orators of the ancient republics: and the moment, when Mark Antony uncovers and shews to the Roman people the bloody corse of the first of the Cæsars, is not the least eloquent passage of his harangue.

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* Consult J. A. Borelli, *de motu animalium*, 4to. The errors contained in this work depend on the circumstance of the author's being more of a mathemation than of an anatomist.

P. J. Barthez, *nouvelle Mechanique des mouvemens de l'Homme et des animaux.*

Thus, although the organ of voice is that which offers us the greatest abundance of resources for the expression of our ideas, for communication with our fellow creatures,—though the hearing be the sense to which we must address ourselves to produce in them distinct, varied, and lasting impressions,—we do yet address ourselves to their touch and their sight, when we would strongly move them, by an energetic declaration of our desires. These three different languages are employed at once, when we lead a man towards an object, and at the same time point it out to him, and bid him go there: touch and gesture are then auxiliary to speech, and testify in him who makes use of them, a strong and resolute will. The motions of the eyes, the eye-brows, the eye-lids, the lips, and, generally, of all parts of the face, those of the upper limbs, and of the trunk itself, serve to express our passions, as well as our ideas, are supplemental to the language of convention, and often betray it, by saying the reverse of what it expresses. The study of gestures, of motions, and of attitudes, considered as signs of ideas and passions, is the department of metaphysicians, of painters, of sculptors, and physiognomists.*

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* See Condillac's Essay on the Origin of Human Knowledge; Buffon's Natural History of Man; Winkelmann's Treatise on Art; Lavater's Essays on Physiognomy; with the important additions by M. Moreau (de la Sarthe,) in the edition he has just published

CHAPTER IX.

OF VOICE AND SPEECH.

CXCIV. The voice is an appreciable sound, resulting from the vibrations which the air, expelled from the lungs, meets with, in passing through the glottis. From this sound, articulated by the motions of the tongue, the lips, and other parts of the mouth, is produced *speech*, which may be defined *articulated voice.*

All animals furnished with a pulmonary organ have a voice; for it is sufficient, to the production of this sound, that air, collected in any receiver, be driven out in a body, with a certain force, and that it meet, on its passage, with elastic and vibratory parts. Fish, that have only tracheæ, utter no sound: but this defect, which is certainly an impediment to the extent and facility of their relations, is in part made up by the extreme velocity of their progressive motion.

The instrument of voice is the larynx, a sort of cartilaginous box, placed at the upper part of the trachea. The thin and elastic cartilages which form its parietes are united by membranes, and moved on one another by many little muscles, called laryngeal. Of these five cartilages, three only are concerned in the production of voice, these are the arytenoid and the thyroid. The epiglottis is of no other use than to close, to what we swallow, the entrance of the windpipe, whilst the cricoid, situated at the lower part of the organ, serves it for a base, on which the arytenoid, and the thyroid execute the motions, by which the opening of the glottis is contracted or enlarged, for the formation of acute or grave tones.

This slit, from ten to eleven lines long in an adult, and from two to three wide, where the width is greatest, is the most essential part of the larynx. It is really the organ of voice, which is gone at once, when, by opening the trachea, or the larynx below it, the air is prevented from passing through it. Speech only is lost, when the wound is above the place of the glottis; which shews that voice and speech are two distinct phenomena, one taking place in the larynx, and the other resulting from the action of divers parts of the mouth, and especially the lips.

Are the different modifications of which the voice is susceptible, dependent on the width or straightness of the glottis, or on the tension or relaxation of the ligaments forming its sides? Must we believe, with Dodart, that the larynx is a wind instument; or, with Ferrein, that it is a stringed instrument?

It is very true that the voice becomes stronger, fuller, and passes from the acute to the grave, as the glottis enlarges with the progress of age;—that it remains always weaker and sharper in a woman, whose glottis is nearly a third smaller than a man's;—but the tension or relaxation of the ligaments, which form the sides of the glottis, (the vocal strings of Ferrein) may they not enable these ligaments to execute, in a given time, vibrations more or less prolonged, and more or less rapid, in such a manner, that if the air, expelled from the lungs by expiration, strike upon them in the state of tension, produced by the action of the crico-arytenoidei postici, which carry back the arytenoid cartilages to which the ligaments of the glottis are attached, whilst the thyroid cartilage, to which are attached the other extremities of the same ligaments, is carried forward by a sort of tilting, occasioned by the muscles connecting it with the cricoid cartilage, (crico-thyroidei*) the voice will be shrill, that is clear and piercing; whereas it would be grave, if the arytenoid cartilages being brought forwards by the action of the crico-arytenoidei obliqui, and the thyro-arytenoidei muscles, the vocal strings, relaxed, executed less frequent vibrations?

It has been objected to Ferrein, that to perform the office of vibrating strings, the ligaments of the glottis are neither dry, nor tense, nor insulated, the three-fold condition required for the production of sound, in the instruments to which this anatomist has compared the larynx: but for all the incompleteness of their resemblance to strings, the ligaments of the glottis, similar to the vibratory bodies, serving as mouth-pieces to wind-instruments, such as the reed of the oboe, the mouth-hole of flutes, the lips themselves in the horn, do not the less contribute to the formation and varied inflexions of the vocal sound. It is the more difficult to set aside their influence altogether, inasmuch as their state of tension coincides always with the contraction of the glottis, and the two conditions producing the same effect, it is difficult to determine if it be due to one rather than the other, as it is impossible to decide whether it be to the enlargement of the opening, or the relaxation of the ligaments, that the grave tones are owing. A last reason, which, I think, should make the larynx be considered as serving at once the purposes of a wind and a stringed instrument, is, that the ligature or section of the recurrent nerves, which give to its muscles their contractility, takes away the voice: so that there is evidently required some kind of action in the sides of the opening.

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* The arytenoid muscle is used in the formation of acute sounds, for bringing together the two arytenoid cartilages.

When we wish to speak low, we contract but slightly, or not at all, the muscles of the larynx, whose action is entirely under the direction of the will. The column of air meeting, then, in its passage along the glottis, only relaxed parts, and little capable of vibration, the vocal sound is no longer produced. The permanent extinction of the voice, must depend, in most cases, on palsy of the vocal or laryngeal muscles.

It appears then, that, rejecting the opposite and exclusive explanations of Ferrein and Dodart, we are to consider the larynx as an instrument combining the advantages, and exhibiting the double mechanism of wind and stringed instruments; it is on this account that it surpasses all musical instruments, by the extent, the perfection, and above all, by the inexhaustible variety of its effects. There is no one, that has heard, at a concert, a solo on the French horn by an able performer, but has been struck with the resemblance of the effects of this instrument, and those of the human voice. It is because the vibrating body at the mouth-piece of the instrument, is alive: it is because the lips, like the sides of the glottis, are moveable, the opening of the mouth dilates and contracts, and, at the same time, its edges are relaxed or stiffened by the contraction of the muscles of the lips.

The modifications of the voice, depend, not only on the varied sizes of the opening of the glottis, and of the tension of its ligaments, but further on the degree of length of the trachea. The singer who runs down the whole scale of sounds, from highest to lowest, visibly shortens the neck and the trachea, whilst in ascending, he stretches them out.

The force of the voice* depends on the volume of air that may be expelled from the lungs at once, and on the degree of aptness, in the parietes of the canals by which it is given out. Birds, whose body is all aerial, have a voice very strong for their bulk. Their trachea, furnished with a double larynx, is almost* entirely cartilaginous. It is especially so in certain screaming birds, as the jay, and some others: whilst it is nearly all membranous in the hedge-hog, a small quadruped, whose cries are almost imperceptible.

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* Sailors, and those that live on the banks of great rivers, have commonly strong voices from being obliged to overpower, with the voice, the noise of the waves, which has constrained them to a great habitual exertion of its organs.

The hissing of serpents, and the croaking of frogs, are heard to some distance, because the creatures can send out a large quantity of air, at once, from their vesicular lungs, and in the last, because the vocal strings are completely insulated from the coats of the larynx, with which in other animals, they are continuous.

The voice of men is strong according to the capacity of the chest. It is always weaker after meals, when the stomach and intestines, distended with food, push up the diaphragm and resist its descent. The voice, formed in the passage of the air along the glottis, acquires much force and intensity, becomes much more sonorous, by the reverberations of the sound in the mouth and in the nasal cavities. It is weakened and disagreeably impaired, when a polypus of the nasal canals, or of the throat, or the destruction of the roof of the mouth, prevents the air from passing along the nasal canals, and their various sinuses. The voice is then said to be nasal, though, in truth, it suffers from want of the modifications it should receive in the cavities belonging to the nose.

CXCV. *Of speech.* To *whisper* is to articulate very weak sounds, which, in truth, deserve not the name of voice, since they scarcely exceed the sound, which always accompanies the passage of air in expiration. Man only can articulate sound, and enjoys the gift of speech. The particular disposition of the mouth, of the tongue, and lips, makes all pronunciation impossible to quadrupeds. The monkey, in whom these parts have the same conformation as in man, would speak like him, if the air as it leaves the larynx, were not diffused into the hyo-thyroid cavities, which are membranous in some, cartilaginous and even bony in the howling monkey, whose cry is so hoarse and melancholy. Every time that the animal would utter his cry, these sacs swell, then empty themselves, so that he is not able, at will, to supply to the different parts of his mouth the sounds they might articulate.*

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* See the Memoirs of M. Cuvier on the double larynx, and on the voice of birds.

Articulated sounds are represented by letters which express their whole force. One cannot reflect on it all, without seeing what an advance man made towards the perfection of his nature, when he invented these signs for the preservation and transmission of his thoughts. The vocal sounds are expressed by the letters called *vowels*, that is to say, which the voice furnishes almost completely formed, and which need, for their articulation, nothing more than the more or less opening of the mouth, by the separation of the jaws and of the lips. We pronounce, without effort, the letters A, E, I, O. U; they are the first the child utters; they appear, besides, to cost him less study than the consonants. These, which form the most numerous class of the letters of the alphabet, serve only, as their name indicates, to bind together the vowels. Their pronunciation is always less natural, and consequently more difficult. Accordingly, it is observed, that the most harmonious languages, the most grateful to the ear, are those which use fewest consonants and most vowels. It is in this point especially, that the Greek tongue surpasses all, ancient and modern†; that, of dead languages, Latin holds the second place; and, lastly, that Russian, Italian, and Spanish, are more agreeable in pronunciation, than French, and still more than languages of Teutonic origin, as English, German, Dutch, Swedish, Danish, &c. Among some Northern nations, all articulated sounds appear to issue from the nose or the throat, and make a disagreeable pronunciation, no doubt, because it requires greater effort, and he who listens sympathizes in the difficulty which seems to be felt by him who speaks. Would it not seem that the inhabitants of cold countries have been led to use consonants rather than vowels, because the pronunciation, not requiring the same opening of the mouth, does not give the same room to the continual admission of cold air into the lungs. The gentle pacific nature of the inhabitants of Otaheite, and of the other Fortunate Isles of the South Sea, is shewn in the words of their language, in which are abundance of vowels, whilst the hard and barbarous speech of the Esquimaux, of the people of Labrador, and New Zealand, is the natural consequence of the rigour of their climate, the barrenness of their soil, and their ferocious and warlike habits.

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* In the ass, an analogous structure is observed.

† —— *Graiis dedit ore rotundo*
Musa loqui.—Horat.

The distinction of letters, into vowels and consonants has not been thought sufficient: they have been further distinguished, according to the parts which are more especially engaged in the mechanism of their pronunciation. Thus we mark the *labial*, *oral*, *nasal*, and *lingual vowels;* and *semi-vowels*, M, N, R, L, which bear different names, according as the tongue, in articulating them, strikes the roof of the mouth, the teeth, or the lips: lastly, *explosive* consonants, K, T, P, Q, G, D, B, P, and *sibilant*, H, X, Z, S, J, V, F, C, which are more numerous and more frequently employed in languages of more difficult pronunciation. If information on this subject could be of real utility, I should explain the mechanism of the pronunciation of every letter of the alphabet, at the risk of furnishing a new scene to the *Bourgeois Gentilhomme.*

CXCVI. *Singing*, *stammering*, *dumbness*, *ventriloquism.* *Singing* is nothing more than voice modulated, that is, running over, with varying rapidity, the different degrees of the harmonic scale, passing from the grave to the acute, and from the acute to the grave, with expression too of the intermediate tones. Though, in general, our song is spoken, speech is not necessary to it. This action of the organs of the voice requires more efforts and motions than speech: the glottis enlarges or contracts, the larynx rises or descends, the neck stretches out, or is drawn in; inspiration is accelerated, prolonged, or slackened; expiration is long, or short and abrupt. Accordingly, all these parts are more fatigued than by speech, and it is impossible for us to sing as long as we speak.

Whatever Rousseau may have said, in his Dictionary of Music, singing may be regarded as the most natural expression of the emotions of the soul, since the least civilized nations so use it, in their songs of war and love, of joy and mourning: and, as every affection of the mind modifies, in some way, the voice, music, which is only imitated song, can, by the aid of sounds, paint love or rage, sadness or joy, fear or desire, can produce the emotions of these different states, can thus sway the course of our ideas, and direct, at pleasure, the operations of the understanding, and the acts of the will*. Of all the instruments which this art employs, the vocal organ of man is, indisputably, the most perfect, that from which the most agreeable combinations and the most varied may be obtained. Who is there that knows not the property of the human voice to lend itself to all accents, and to imitate all languages†? I will observe, on the occasion of song, that it is especially consecrated to the expression of tender sentiments or movements of passion, and that it is turning it aside from its natural or primitive destination, to employ it in situations where no emotion can be supposed. It is this that makes the recitative of our operas so intolerably tiresome, and throws such ludicrousness over dialogues where the speakers converse singing, on the most indifferent matters. Languages abounding in vowels, are thereby fitted to song, and favour the growth of musical genius. It is perhaps their smooth and sonorous language that has given to the music of the Italians, its superiority over that of other countries‡. The declamation of the ancients was much more removed than our own, from the common tone of conversation, approached nearer to music, and might be noted like real song.

The pleasantness, the precision of the voice, the extent and variety of inflexions of which it is capable, depend on the good conformation of its organs, on the flexibility of the glottis, the elasticity of the cartilages, the particular disposition of the different parts of the mouth and nasal canals, &c. It would be enough that the two halves of the larynx, or the two nasal canals, were unequally developed to prevent precision and distinctness of voice.

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* See Grétry, *Essais sur la Musique, &c.*

† See in the *Aviceptologie Française*, or *Art de prendre toutes sortes d'Oiseaux*, the way in which they are drawn into snares by counterfeiting their song.

‡ This pre-eminence has been strongly contested, especially in France, where towards the middle of the last century, a war arose on the subject, in which her whole literature, split into two factions, fought for the superiority of Piccini and Gluck. Out of the heaps writings in verse and in prose, with which the contest was carried on, a few epigrams will be remembered, the letter of Rousseau on French music, and the little work of D' Alembert on the liberty of Music. Marmontel too has made these disputes the subject of an unpublished Poem, under the name of *Voyagés de Polymnie*

Stammering is a vice of pronunciation too well known to make it necessary to define it. A tongue too bulky and thick,—a remarkable diminution of irritability, as in drunkenness, at the approach of apoplexy, and in certain fevers of a malignant kind,—the too great length of the frænum of the tongue,—by hindering the readiness and ease of its motions, become causes of stammering. Or it may be produced by the want or bad arrangement of several teeth. The same causes, but especially the length of the frænum of the tongue, keep down this organ against the lower paries of the mouth, and hinder its point from striking the anterior part of the roof of the mouth with the quick stroke, requisite for the pronunciation of the letter R. The name of *burr* is given to this defect of speaking.

As for *dumbness*, it may be either accidental or from birth. When by any accident, as from a gun shot wound, a cancerous tumour which has rendered necessary the extirpation of part of the tongue, that organ, so far destroyed, is no longer able to apply itself to the different parts of the parietes of the mouth and combine its motions with those of the lips, then the person becomes dumb, that is to say, deprived of speech. He has still voice, or the faculty of uttering sounds: he may even articulate, if he supply, by mechanical means, the parts of the tongue, lips, or roof, the want of which hinders his pronunciation.

It is not so with the dumb from birth. Frequently, all parts of the mouth are perfect in their conformation, and yet the child cannot attain to speech. Such is the case of a little boy of three years and a half old, who has been brought to me, to divide his frænum linguæ. Sometimes, however, the tongue adheres to the lower part of the mouth, because the internal membrane of that cavity is reflected over its upper surface, long before it reaches the the middle line of the inferior surface. In other cases, the edges of the tongue adhere to the gums.

Sometimes, also, the tongue is really paralytic; such was the case of the son of Crœsus, whose wonderful story is related by Herodotus*.

In the deaf and dumb from birth, the dumbness always arises from the deafness: this, at least, is what M. Sicard has observed in the great number of pupils committed to his care: which has led him to say, that, in them, the want of speech should bear the name not of dumbness, but of silence. It is owing entirely to the absolute ignorance of sounds, and of their force represented by the letters of the alphabet; the organs of voice shew no trace of injury; they are well fitted for fulfilling the purposes to which they were allotted by Nature: but they remain inactive because the deaf child cannot be taught to use them.

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* This is the author's solution of the story, not Herodotus's statement, who says expressly the boy was deaf. But the conjecture is ingenious, and shews a possibility in the story, which, as Herodotus tells it, is impossible.

It was necessary, therefore, as the ear was closed, to address to other senses the speech he must endeavour to imitate. His eye must be made to watch the motions* of the lips and the tongue; his hand to feel the vibrations, and the utterance of sound; and thence he must learn to use his organs of speech: this has been done. What Pereira had begun, Sicard has brought to perfection*: and such command of articulate sounds has been given to the deaf and dumb by birth, as has enabled them to utter words, and connected discourse. Even something of inflexion of strong and weaker tones has been taught them by using the arm as a regulator, as pedals are employed to modify the touches of the pianoforte.

But instruction to the deaf and dumb must be given them by another language. Written language they learn, not as a representative of speech, but as hieroglyphic characters for ideas: and a manual language, in which each letter is expressed by the position of the fingers or hands, is used as a more convenient and rapid representation of that hieroglyphic language of written characters. It is by this that conversation with them is best carried on; and it is with an ease and rapidity which astonishes those, who, for the first time, are witnesses to the use of it.

To conclude this chapter, I have still to speak of a phenomenon, well worthy, by its singularity, of the attention of physiologists. It is known under the name of *ventriloquism*, because the voice weak, and little sonorous, appears to issue from the stomach. There is now living, at the quondam Palais-Royal, at the Coffee-House de la Grotte, a man, who can carry on a dialogue so naturally, that you would think you were listening to the conversation of two people, at some distance from one another, and quite different in voice and tone. I have observed, that he is not inspiring while he speaks from his belly, but that less air comes from his mouth and nostrils than in his ordinary speaking. Every time that he does so, he finds a swelling in the epigastric region; sometimes he feels wind moving lower down, and cannot go on long together without fatigue.

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* It is known, that old men, grown deaf, fix their attention very closely on the motions of the lips, as well as on the varying expressions of the face, to see the words as well as thoughts of those who are speaking.

I had at first conjectured that, in this man, a great part of the air driven out by expiration, did not issue from the mouth and nasal fossæ, but that, being swallowed and carried down into the stomach, it struck against some part of the digestive tube, and produced a real echo, but having since observed, with the greatest care, this curious phenomenon in M. Fitz-James, who exhibits it in the highest perfection, I have satisfied myself that the name of ventriloquism no ways suits it; since its whole mechanism consists in a slow, gradual, attenuated, expiration, whether for that purpose the artist employ the power of the will upon the muscles of the parietes of the chest, or whether he hold the epiglottis slightly lowered, by means of the root of the tongue, of which he scarcely brings the point beyond the dental arches.

I find this long expiration always preceded by a strong inspiration, by means of which he introduces into his lungs a large quantity of air of which he afterwards husbands the use. Accordingly, repletion of the stomach is a great hinderance to the action of M. Fitz-James, by preventing the descent of the diaphragm which the chest would require, to dilate itself for the full quantity of air the lungs should receive.

By accelerating or retarding expiration, he can imitate different voices, make it seem that the speakers, in a dialogue, which he carries on by himself, stand at different distances, and produce illusion the more complete, the more perfect is his talent. No one equals M. Fitz-James in the art of deceiving, in this respect, the most wary and suspicious observer.

He can set his organ to five or six different tones, pass rapidly from one to the other, as he does when he represents a very eager discussion, in a popular society of the people, imitate the sound of a bell, and carry on, singly, a conversation, in which one might think that several persons of different ages and sexes were taking parts. But what completes the illusion and especially distinguishes the art of the ventriloquist from that of the mimic, who can only counterfeit, consists in the power of so modulating his voice that one is deceived as to the distance of the speaker, in such sort, that one voice, comes from the street, another, from a neighbouring apartment, that, from one that had clambered up the roof of the house, &c. It is easy to discern the value of such a talent in the days of oracles.

SECOND CLASS.

FUNCTIONS

SUBSERVIENT TO THE PRESERVATION OF THE SPECIES.

CHAPTER X.

ON GENERATION.

CXCVII. *Differences of the sexes.* The functions treated of in this chapter are not necessary to the life of the individual, but, without them, the human species would soon perish, for want of the power of reproduction; these functions, destined to preserve the species, are entrusted to two kinds of organs, belonging to the two sexes, of which they constitute the principal, though not the only difference.

Woman, in fact does not differ from man, in her genital organs merely, but, likewise, in her lower stature, in the delicacy of her organization, in the predominence of the lymphatic and cellular systems, which softens down the projections of the muscles, and gives to all her limbs those rounded and graceful forms, of which we see, in the Venus of Medicis, the inimitable model. In woman, sensibility is also more exquisite; and with less strength, her mobility is greater. The female skeleton even is easily distinguished from that of the male, by striking differences. The asperities of the bones are less prominent; the clavicle is less curved, the chest shorter but more expanded, the sternum shorter but wider; the pelvis more capacious, the thigh bones more oblique*, &c. In a dissertation on physical beauty, read by Camper to the Academy of design, at Amsterdam, this celebrated physiologist shewed, that, in tracing the forms of the male and female body within two elliplical areas, of equal size in both, the female pelvis would extend beyond the ellipsis, and the shoulders be within; while, in man, the shoulders would reach beyond their ellipsis, and the pelvis be contained within its limits.

The general characters of the sexes are so marked, that it would be possible to distinguish a male, merely by seeing a part of his body naked, even though this part should not be covered with hairs and should have none of the principal attributes of virility. Should this difference of organization and character be ascribed to the influence of the sexual organs upon the rest of the body? Does the uterus impress on the sex all its characteristic modifications, and is it just to say with Vanhelmont: *Propter solum uterum mulier est, id quod est*; the uterus alone makes woman what she is. Though this viscus, very evidently, re-acts on the whole system of the female, and seems to draw under its controul nearly the whole of the actions and affections of woman, I am, nevertheless, of opinion, that it is far from being the only cause of her distinguishing characteristics, since these may be recognized, from the earliest period of life, when the uterine system is far from having attained its full activity. A very singular fact, recorded by Professor Cailliot, in the second volume of the Memoirs of the Medical Society of Paris, proves better than all the reasoning in the world, how much the character of the sex is independant of the influence of the uterus. A female was born and grew up with all the external characteristics of her sex. At the age of twenty-one, she wished to yield to her desires, but found it impracticable; there was nothing beyond the vulva, in other respects, well formed. A small canal, between two and three lines in diameter, occupied the place of the vagina, and terminated in a cul de sac, and was about an inch in depth. The most accurate examinations, by introducing a sound into the bladder, and the finger up the rectum discovered nothing like the uterus. With the finger in the rectum, the convexity of the sound in the bladder, could be distinctly felt, so that it was evident that, between the lower part of the bladder and the anterior part of the rectum, there lay no organ corresponding to the uterus. The young woman had never been subject to the periodical evacuation which accompanies or precedes the time of puberty. No hemorrhage supplied the place of this excretion. She experienced none of the indispostions that are occasioned by the absence of menstruation; she enjoyed, on the contrary, the most perfect health; she was deficient in none of the other characteristics of her sex, only that her breasts were small. At the age of twenty six or twenty seven, she became subject to a pretty frequent evacuation of bloody urine. May not this affection, which recurred at irregular periods, be considered as a means by which nature supplied the deficiency of the menstrual evacuation? The bladder, in that case, would fulfil the office of the uterus and its capillary vessels must have been considerably evolved.

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* Compare the beautiful plates of the male and female skeleton by Albinus and Sœmmering.

The reproduction of the species is, in woman, the most important object of life; it is almost the only destination to which Nature has called her, and the only duty she has to fulfil in human society. Wherever the earth is fruitful, and furnishes man with abundant means of providing for his wants, he dispenses with the services of woman, in obtaining from it means of subsistence, he releases her from the burthen of social obligations. The Asiatic expects from the women he maintains in his seraglio, in a state of inactivity, nothing but pleasures and children to perpetuate his race. The women of Otaheite have no employment but pleasure and the duties of mothers. Among some of the savage tribes of America, man, abusing the odious right of power, tyrannizes, it is true, over woman, and reserving to himself all the advantages of social life, makes her bear all its weight; but this exception does not invalidate the general law deduced from observation of all nations. Whatever withdraws woman from this primitive destination; whatever diverts her from this end is to her injury; it is the scope of all her actions and habits, every thing, in her physical organization, has evident reference to it. Of all the passions, in woman, love has the greatest sway; it has even been said to be her only passion. It is true, that all the others are modified by it, and receive from it a peculiar cast, which distinguishes them from those of man*.

We will enter, no further, into the examination of the general differences which characterize the two sexes; no one has entered more deeply into this subject, or has treated it in a more interesting manner, than M. Roussel, in an excellent work entitled; *Système physique and moral de la femme.*

CXCVIII. *Hermaphrodism.* Hermaphrodism, or the union of the two sexes in the same individual, is impossible in man, and in the numerous class of red-blooded animals. There is, on record, no well authenticated case of such a combination; and all the hermaphrodites, that have been hitherto met with, were beings imperfectly formed; in whom imperfect male organs, or female organs unnaturally enlarged, rendered the sex dubious. None was ever found that had the power, by itself, of begetting a similar being to itself: the greater number were incapable of reproduction; the imperfection, or the faulty conformation of their organs, condemned them to barrenness. Such was the case with the hermaphrodite mentioned by Petit of Namur, in the Memoirs of the Academy of Sciences; with that one whose case is related by Maret, in the Memoirs of the Academy of Dijon, and with all those to be found in the records of the Medical Society, which contain the greatest number of facts of this kind.

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* Fontenelle used to say of the devotion of some women: *One may see that love has been here.* It has been said in speaking of St. Theresa: *To love God is still to love.* Thomas maintains that, *with women, a man is more than a nation. Love is but an episode in the life of man; it is the whole history of the life of woman.* (Madame DE STAEL).

But though, in man, and in all beings that most resemble him, in their organization, complete hermaphrodism has never been met with, it is a frequent occurrence among the white-blooded animals, and especially among the plants that occupy the lowest part of the scale of organized beings. The same is observed in polypi, in several kinds of worms, in oysters, and snails. The latter present a singular variety of hermaphrodism,in this,that the male and female organs being combined in the same individual it is still singly, not capable of generation, but is obliged to copulate with another being likewise an hermaphrodite, so as to receive, from friction and other means of irritation, the excitement to the act of reproduction.

In the immense tribe of monœcia plants, the male and female organs are combined on one stalk, and even sometimes within the same flower. A number of stamina surround one or more pistils, shed on the stigma their fertilizing dust or pollen, which is conveyed, along the canal of the style, into the ovary, there to impregnate the seeds by means of which the species are perpetuated. The same vegetable species containing, sometimes, male and female individuals, the sexes may be at considerable distances from one another; the seminal dust is, in that case, conveyed by the air, from the male to the female. This is the case with palm trees on which Gleditsch made his first observations on the generation of plants; hemp, spinage, mercurialis, &c.

CXCIX. It is a distinction of the human species that, in them, the functions of generation are not under the influence of the seasons. The lower animals, on the contrary, draw together, and pair at stated periods of the year, and seem afterwards to forget the enjoyments of love, that they may attend to their other necessities. Thus, wolves and foxes copulate in the middle of winter; deer, in autumn, most birds in spring. Man alone seeks his partner at all seasons of the year, and impregnates her under all latitudes and in all temperatures. This privilege is not so much the consequence of his peculiar constitution, as a result which he derives from his industry, protected by the shelters which he constructs against the inclemency of the seasons, and the variations of the atmosphere; always capable of gratifying his physical wants by help of the stores which is foresight has led him to collect, he can, at all times, indulge in the enjoyments of love. The domestic animals which we have, in great measure, removed from the influence of external causes, bring forth almost indiscriminately, at all seasons of the year. To prove still further, that it is from counteracting, by the resources of his industry, the influence of nature, that man has succeeded in resisting the influence of the seasons, in the reproduction of his species, I may observe, that this effect of temperature is more absolute, the farther the species is from man: hence the spawn of fishes and frogs is productive sooner or later, according to the earliness or lateness of the season, and thus, a great number of insects depend on the heat of the weather for their powers of reproduction, and for their existence.

CC. *Of the organs of generation in man.* Aristotle, Galen, and their verbose commentators, have expressed the analogy which subsists between the organs of generation, in the two sexes, by saying that they differ only in their position, being external in man, and internal in woman. There is, in fact, a considerable resemblance between the ovaria and the testicles, the fallopian tubes and the vasa deferentia, the uterus and the vesiculæ seminales, the vagina, the external organs of generation in women, and the male penis. The former secrete the seminal fluid and furnish, in man or in woman, a matter essential to generation (*ovaria and testicles*). The fallopian tubes, like the vasa deferentia, convey this fluid into receptacles where it has to remain for some time (uterus and vesiculæ seminales). These contractile cavities, which serve as reservoirs to the semen, or its product, part with these substances, when they have remained within them a sufficient length of time; lastly, the vagina and penis serve to expel them. However striking such analogies may be, we are not justified in inferring a perfect resemblance between the organs of generation in the two sexes. Each of them fulfills, in the act of reproduction, functions perfectly distinct, though of reciprocal necessity.

The prolific fluid is secreted by the testicles; these organs are two in number, covered by several coats, one of which, covered by the skin, and known under the name of scrotum, resembles a bag containing both these organs, it contracts on the application of cold, is relaxed by heat, and possesses a degree of contractility more evident than in the other parts of the cutaneous tissue. The dartos forms a second cellular envelope common to each testicle. The tunica vaginalis,a serous membrane affords an immediate covering to them, and reflecting itself over their surface, is disposed with regard to them, as the peritoneum with regard to the abdominal viscera, that is, it does not contain them, within its cavity. Lastly, the testicles are covered by a fibrous, white, thick, and very consistent membrane; it is termed tunica albuginea, from the inner surface of which there arise a considerable number of membranous laminæ, which, crossing one another, within its cavity, form cells containing a yellowish vascular substance. This substance contained within the tunica albuginea, has so little consistence, that it would very soon be dissolved, if the testicle were stripped of its outer covering. It is formed by the seminiferous tubes, which are small capillary vessels extremely tortuous and coiled on themselves, arising, probably, from the extremities of the spermatic arteries, all directed towards the upper part of the oval formed by the testicles, joining in this place, and forming about ten or twelve tubes which unite into a cord situated within the tunica albuginea, called the *corpus Highmorianun*. The ten or twelve ducts which unite into a fasciculus, and form this cord, pass through the membrane within which they are contained, unite into a single canal which is convoluted, and forms a substance called the epididymis. This canal, formed by the union of the ducts of the corpus Highmorianum, at first convoluted on itself, becomes less and less tortuous, as it approaches the lower extremity of the testicle; there it bends back and ascends under the name of *vas deferens*, along the spermatic cord, as far as the inguinal ring, by which it enters the abdominal cavity. The vasa deferentia, though of the size of a quill, have, nevertheless, a very small cavity, and it is not easy to say why a capillary tube should have such thick parietes, and nearly as hard as cartilage.

The semen, secreted by the testicles, is formed from the blood conveyed to them by the spermatic arteries, long, slender, and very tortuous vessels, arising from the aorta, at a very acute angle. This fluid is filtered through the seminiferous tubes, passes into those of the corpus Highmorianum, and thence into the vasa deferentia, which, after they have entered the abdomen, terminate into the vesiculæ seminales, and deposit into them the spermatic fluid. The delicacy of the organization of the testicle, the delicacy of the vessels along which the semen is conveyed, account for its tendency to congestion, and for the difficulty with which a resolution of this affection is obtained.

The spermatic fluid passes from the vasa deferentia, into the vesiculæ seminales, notwithstanding the retrograde direction of their course. The cavities serving as receptacles to the semen, resemble, in this respect, the gall bladder. Notwithstanding the unfavourable direction in which the ducts of the liver and of the testicles join their respective receptacles, they nevertheless convey their fluids into the latter; the bile, because the ductus choledochus is pressed by the coats of the duodenum, contracted on itself when empty; the semen, because the duct along which it is conveyed, penetrating through the prostrate gland, and opening into the urethra, by a very narrow orifice, this fluid flows back more readily into the vesiculæ seminales, than from the vas deferens into the ejaculatory duct.

The vesiculæ seminales form two membrancus receptacles of different capacity, in different individuals, larger in young people and adults, than in children and old people. Their cavity is divided into a number of cells; they are lined with a mucous membrane which secretes, in considerable quantity, a viscid humour that mingles with the semen, increases its quantity and serves as a vehicle to it. The situation of the vesiculæ seminales, between the rectum, the levatores ani, and the posterior part of the bladder, promotes the excretion of their contents (which is chiefly brought about by the contraction of their parietes), by the compression of the levatores ani, which are in a state of convulsion at the moment of emission. Animals that are not provided with these seminal receptacles remain a considerable time in a state of copulation, the prolific fluid necessary to impregnation having to be secreted during the time that the copulation lasts, and flowing in drops.

The ducts formed by the union of the vesiculæ seminales with the vasa deferentia, pass through the prostate gland and open, by separate orifices, into the urethra, at the bottom of a lacuna, near the verumontanum. The glandular body in which they are inclosed, and which contains both the neck of the bladder and the beginning of the urethra, does not exist in women. The mucous and whitish fluid, secreted by the prostate, is conveyed by ten or twelve orifices into the urethra. This prostatic fluid mingles with the semen, adds to its quantity, is perhaps emitted first, in order to lubricate the internal surface of the canal, and prepare it for the passage of the seminal fluid, by rendering the internal surface of the urethra more slippery. The use of the urethra is, not only to convey the semen out of the body, but likewise to serve in the excretion of the urine, and to form a part of the penis. The latter destined to convey the prolific fluid into the female organs of generation, must be in state of erection to perform this function completely. Erection being a phenomenon of structure, that of the penis will be considered, after the description of the female organs of generation.

CCII. *Of the female organs of generation.* I shall not adopt the anatomical arrangement generally followed in this description, but classing in three divisions, the different parts which, in women, are subservient to the genital functions, I shall speak first of the ovaria and fallopian tubes, then of the uterus and, in the last place of the vagina and external parts.

The ovaria, situated in the female pelvis, connected to the uterus by a ligament, receive the vessels and nerves which, in women, are sent to the testicles; they resemble in form the latter, but are somewhat smaller. Do the ovaria secrete a fluid, which, by mixing with the male semen, produces the new being, or is there detached from them, at the moment of conception, an ovum which the semen vivifies. Whatever opinion is adopted, one is compelled to admit, that the ovaria prepare a substance essential to generation, since females, in whom these parts have been extirpated, are

It is, likewise, unquestionably, along these membranous tubes, called fallopian, that this substance, whatever it may be, furnished by the ovaria, passes into the uterus, into which one of their extremities opens; while the other extremity, broad and fringed, lies loose in the cavity of the pelvis, supported by a small duplicature of the peritoneum, but undergoes a state of erection and applies itself to the ovarium, during the act of coition, and forms a continuous canal between that organ and the cavity of the uterus. The external orifice of the fallopian tube, called *corpus fimbriatum*, has been found grasping thus the ovarium, in females opened immediately after coition. It may happen, from a malformation of the parts, that the fallopian tube may not be able to apply itself to the ovarium; I dissected at the Hospital *de la Charité*, the body of a woman who had been barren; and found the corpora fimbriata, or the expanded terminations of the fallopian tubes adhering to the lateral parietes of the pelvis, so that it was impossible they should perform the motions required for impregnation.

The uterus, lying in the pelvis, between the rectum and bladder, is a hollow viscus, in which the fœtus grows till the period of birth. Its internal part has been found separated into two cavities, opening, in some cases, in the same vagina and, at others, terminating in a vagina that was double, only in the immediate vicinity of the uterus. Valisnieri mentions the case of a woman who had a double uterus, the one opening in the vagina, and the other communicating with the rectum. Though the muscularity of the parietes of the uterus becomes manifest, in proportion as this organ enlarges, during the progress of pregnancy, this hollow muscle may be said to differ from other muscular organs, by the arrangement of its fibres, which it is difficult to discover while its cavity is empty, and which it is even impossible completely to unravel, while it contains the fœtus; its most remarkable distinguishing character, is its singular property of dilating and stretching itself, and, at the same time, of gaining in thickness instead of becoming thinner.

The vagina is remarkable, only by the soft, wrinkled, and easily dilated structure of its parietes. The upper extremity of this oblique canal, which is directed upward and backward, embraces the cervix of the uterus, while its lower orifice is surrounded by a spungy body, whose cells fill with blood and expel it, like the corpora cavernosa of the penis, and clitoris. It is called plexus retiforme; its turgescence, during erection, contracts the orifice of the vagina; the contraction of the constrictor muscle, which answers the purpose of the accelerator urinæ in man, and which lies over this plexus retiforme, surrounds like it, the entrance of the vagina, and may, in the same manner, contract the orifice of this canal.

Besides, this external orifice is furnished, in women who have had no connexion with men, with a membranons fold, varying in breadth, generally semicircular, and called hymen. Its existence is considered by many, as the most certain sign of virginity. But all the marks by which it has been attempted to obtain a certainty of the presence of virginity are very eqivocal.* The relaxed state of the parts, from a great quantity of mucus, in a woman subject to the fluor albus; or from the blood of the menstrual discharge, may make the hymen yield and not rupture, so that a woman might seem a virgin without being such; while another woman who has not lost her virginity, might, from illness, have her hymen destroyed. There are, in the last place, persons in whom the hymen is so indistinct, that several anatomists have doubted its existence.

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* "Attamen prima venus debet esse cruenta."

HALLER.

The other external parts of generation, which are easily discovered, without the aid of dissection, cannot be considered as merely ornamental; all are, as will be shewn, presently, of real utility. The folds of skin which form the labia and the nymphæ, yield, during the delivery of the fœtus. These duplicaures not only unfold themselves, but likewise undergo a degree of extension, their tissue being moister, softer, and more extensible than that of the skin. The mons veneris, the hairs which cover it, the clitoris which resembles an imperfect penis, seem merely organs of voluptuousness; but is not pleasure itself an element in the act by which the human species is reproduced?

CCIII. *Of conception.* When a chemical, mechanical, or mental irritation excites the action of the genital organs, the penis elongates itself, becomes turgid and stiff, from the accumulation of blood within the cells of the corpus cavernosum, and within those of the corpus spongiosum of the urethra.* The turgescence of these two parts of the penis should be simultaneous, to render the erection complete. It has been thought that this phenomenon might be accounted for, by the compression of the pudic veins, which are situated between the symphysis pubis and the root of the penis, which, as long as the erection lasts, is compressed against the bone by the erector muscles. But far from elevating the penis, the muscles of the perineum, especially the ischio cavernous (*erectores penis*,) tend to depress it. The blood which distends the corpora cavernosa of the penis, and the corpus spongiosum of the urethra and glans, which is itself the expanded extremity of the urethra, does not stagnate in their cells, only there is a greater quantity of blood in them, than usual; the irritation increasing, in a remarkable manner, the action of the arteries. Erection, always proportioned to the degree of the stimulus, ceases, when the cause of irritation no longer acts on the penis; in the same manner that an inflammatory tumour is discussed, when the cause is removed†.

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* "Penis adest, ità constructus, ut stimulo corporeo sive mentali irritatus, turgeat et obrigescat, seque erigat, posteà detumescat, et collabatur."

CREVE.

† The animal heat is somewhat augmented, during erection, as well as in inflammation. The temperature of the blossoms of the arum rises several degrees, above that of the atmosphere, at the moment of impregnation.

In this voluptuous dilatation, the urethra is brought into a state of erection, being put on the stretch by the penis which is elongated, its curves are straightened, the irritation is propagated from the external to the internal parts, to the vesiculæ seminales and the testicles. These swell and their secretion is increased, as they receive a gentle degree of motion from the action of the scrotum, which becomes wrinkled and draws them up towards the abdomen, and by the action of the cremaster muscle, whose expansion forms between the tunica vaginalis and the dartos, what has been improperly called the tunica erythroidea; they empty themselves with the greater ease along the vasa deferentia, which decrease in length, as the testicles rise, and which participate in the concussion affecting these organs.

The concussions of the cremaster on the testicle, or on the vasa deferentia, promote, in so important a manner, the secretion and excretion of the semen, that this little muscle is found in animals whose testicles never leave the abdomen, but remain within that cavity on the sides of the lumbar region, as was observed by Hunter in the hedge-hog and the ram. This fact of comparative anatomy shews, that the cremaster is of use, not merely in suspending the testicles as its name indicates, since in the animals above mentioned, they return into the abdomen towards the organ on which, they are to act.

When irritation is carried to a certain length, it acts on the vesiculæ seminales, and these on the fluid which fills their cavity, and they expel it, by the spasmodic contraction of their membranous parietes, assisted, in this excretion, by the levatores ani. (CCI.) The prostrate gland and the mucous glands of the urethra furnish a viscid substance, calculated to promote the evacuation of the seminal fluid which is emitted in jets, more or less rapid.

CCIV. The human semen is never emitted in a state of purity, that is, such as it is prepared by the testicles; it is even conjectured, that the mucous fluid of the vesiculæ seminales forms the greatest part of it. It is this mucus which eunuchs emit in considerable quantity. The fluid secreted by the prostate gland and by the mucous glands of the urethra, affect it, likewise, by uniting with it.

On being received into a vessel, it exhales a peculiar smell like that of the pollen of a great number of plants, for example, of the chesnut tree. It consists of two parts, the one thick and in clots, while the other is viscid, white and more fluid. The proportion of the fluid to the semi concrete part is greater, in proportion as the person is weaker, and as the emission of semen is more frequently repeated, It soon liquefies, by losing part of its weight which always exceeds that of water in which it becomes soluble, though it was not so at first. On being analyzed by M. Vauquelin, it was found to contain: of water 90 centimes—of animal mucilage 6—phosphate of lime 3—soda 1. It is in consequence of this last alkali, that it is enabled to turn syrup of violets to a green colour. The animal mucilage is not pure albumine, but rather a gelatinous mucus, on which the qualities of the semen appear particularly to depend, such as its insolubility in water, its odour and spontaneous liquefaction.

On being examined with the microscope, the semen is seen to contain small animalcules, with a rounded head, a tapering tail, and moving with rapidity. Is the liquefaction of the glutinous and viscid parts of the semen, owing to the motion of these creatures? These microscopic animalcules are to be detected in the semen, only at the period of puberty. It has been thought that they shunned the light; authors have even gone the length of describing their ways and their diseases. The imagination has had much to do with all that naturalists have fancied they saw in these creatures, which they made subservient to their explanations of the mechanism of reproduction. However, it must be confessed, that in all the animal fluids and in the juices of many plants, a certain number of these animalcules may be detected by means of the microscope.

A spasmodic contraction affects, during the expulsion of the semen, not only the organs of generation, but the whole body participates in the convulsive state and the moment of emission is accompanied by a commotion of all its parts; so that it should seem, says Bordeu, that in that instant, Nature forgot every other function, and was solely engaged in collecting her strength and directing it to one organ. This general spasm, this, as it were, epileptic convulsion, is followed by universal depression; this physical lassitude is attended with a sensation of sadness which is not without enjoyment. Does this peculiar sensation, which, according to Lucretius, mingles grief with the most lively enjoyment of which we are capable, depend on the fatigue of the organs, or, in truth, as some metaphysicians have imagined, on the confused and distant notion that occurs to the soul, of its own dissolution?

The penis does not enter the uterus, though the semen does. The os tincæ offers too small a slit, and its thick edges are besides in contact. It would be difficult to conceive that this strait passage should admit even the seminal fluid, if it were not known, that in the moment of copulation, the uterus, from irritation, draws together, and inhales, by real suction, the semen which it craves. Plato compared this organ to an animal living within another animal, controuling all the actions of the living economy, burning to sate itself with the liquor of the male, and digesting it to form a new individual.

The great thickness of the cervix of the uterus has given room for reasonable doubt, if its orifice could dilate sufficiently to admit a fluid of the consistency of semen. Some, therefore, have thought that it was not this fluid itself that penetrated into the cavity of the uterus, but the subtlest of its parts, the most spiritualized, a prolific vapour, to which they have given the name of *aura seminalis*; but, besides that the semen has been found in the uterus, in animals opened immediately after copulation, Spallanzani, in his experiments on the fecundation of frogs, of salamanders, and toads, perceived that, to enable the eggs to produce, it was not enough to expose them to the vapour which rises from the seminal fluid of the male; and that nothing was effected, unless the fluid semen actually touched them, though in ever so small a quantity.

It has been said, that the uterus dilates to receive the semen, constricts itself to retain it, and that this spasmodic contraction of the uterus, felt, as Galen assures us, by women, who preserve enough sang-froid to make observations in that situation, was the most undoubted sign that could be had of the success of the copulation. It is, no doubt, to ensure this retention, that it is customary to throw cold water on the females of some domestic animals, when they go too eagerly to the male. The spasm of the skin, occasioned by the cold striking it, affects the uterus, and hinders the flowing back of the semen which has been thrown into its cavity.

It has also seemed, that women conceived more easily, for a little time, after menstruation; when the mouth of the uterus is less exactly closed than usual.

The seminal fluid, thrown into the cavity of the uterus, passes along the fallopian tubes to the ovaria. It does not diffuse itself in the cavity of the abdomen, because the membranous duct seizes the ovarium, which corresponds to it, grasps it closely, and establishes an uninterrupted canal, from this organ to the uterus. The ovarium, bedewed by the semen, irritated by its contact, lets a fluid escape, or perhaps a little ovum, which passes into the uterus, the same way that the semen reached itself. All that remains to be said, concerning the mechanism of generation, must not be delivered as real, but merely as probable, such is the darkness with which Nature has chosen to envelop this great mystery of the living economy.

After distinguishing the true from the probable, an indispensable duty in every science of facts and observations, like physiology, I shall proceed to state the hypothesis, which appears to me the likeliest on the manner in which the two sexes concur in the production of the new being.

CCV. The fœtuses pre-exist in the ovaria of the females, not that they are there since the creation of the world, as Bonnet believed, and all who, embraced the doctrine of that metaphysical Naturalist: but the ovaria containing his germs are formed by the proper action of the ovarium which secretes them, a fresh proof that all the phenomena of organized bodies, whether for the preservation of the species or of the individual, are effected in the way of secretions. This ovum, produced by the elaboration of the blood which the spermatic vessels carry to the ovaria, contáins the lineaments of the new being: but it is only the sketch, or carcass of it, if this may be applied to what has not yet lived. The seminal fluid must bring it out of this state of inactivity, and, with something of an electrical power, waken it into life. The eggs laid by a maiden hen, will never hatch, though there are in them the rudiments of the chick. The eggs of a frog that has been kept apart from the male, during the whole time of spawning, putrefy in the vessel of water they are kept in: if the male, on the contrary, if sprinkled with his semen, as they quitted her, they will speedily shew some developement of life. Their putrefaction may be prevented, and themselves animated, by shedding on them the spermatic fluid, obtained by the process employed by Spallanzani, in his admirable experiments on artificial impregnation.

It is especially to the labours of this able observer, that we owe what has been unveiled of the mystery of generation, and of the part which each sex bears in this function. It is almost proved, that the male co-operates in it, only by supplying the vivifying principle that must animate the individuals, of which the female furnishes the germs; that thus, his part is the least essential. It is not so difficult as may be imagined, to explain, upon this system, the striking resemblances which are frequently seen between fathers and sons. The imperceptible embryo has, at most, the consistency of a slightly viscous glue. Such a body must be exceedingly impressible, and these men of the male, applied to its surface, must impress on it powerful modifications. The action of the fluid on this yet tender embryo must be like that of a seal, which stamps on the soft wax its own image. The impression is the deeper, the resemblance the more striking, according to the spirit and energy with which the male performed the act of reproduction.

The seminal fluid may, not merely act on the surface of the gelatinous and nearly liquid germ, and modify it externally, but it may penetrate so soft a substance, and impress on it inward changes. It is thus that we are able to explain, not only hereditary likeness, but also hereditary diseases. Nevertheless, it does appear, that the interior parts are derived chiefly from the female, while the outward parts are especially influenced by the male; for, when two animals of different species copulate, their mule, resembles the sire outwardly, and the dam within. It is difficult to shew good reason for the want of the generative faculty in mules. Why are their sexual parts, so well developed, altogether barren?—What secret defect frustrates their action? And why do certain mules, among birds, propagate, and in the same manner, hybrid plants, which are real mules, and not quadrupeds?

The impregnation of the ovum is effected in the ovarium itself, to which the semen is conveyed, as has been said. The ovum, stirred by the action of the semen, and of the fallopian tube, detaches itself from the organ which has produced it, and descends into the uterus, by the peristaltic contractions of the fallopian tube. This canal is susceptible of a retrograde motion. It may be conceived, by considering that having stretched itself, by a real erection to convey the semen to the ovarium, it must, in its return upon itself, cause a flow of the fluid its cavity contains, in a completely inverted direction. This retrogade motion, as Nisbet observes, is assisted by a sort of collapse succeeding the excitation which coition had produced: for, the experiments of Darwin prove that the weakness of the vessels is the cause of this mode of action in their parietes. Spungy as the urethra of man, the fallopian tube brings back the ovum, from the ovarium to the uterus. The extra uterine fœtations afford the proof, that matters are carried on in the manner we have stated. Since fœtuses have been found developed, in the ovarium, in the fallopian tube, and even in the cavity of the abdomen, when the detached ovum has escaped from the grasp of the corpus fimbriatum,* one must admit, that it follows the course which has been described.

The ovaria, like the testicles, swell and enlarge, at the time of puberty. They shrink, and wither in some sort, when the woman is no longer fit for conception. On examination, a few days after conception, one of the ovaria, larger than the other, shews a little yellowish vesicle, which dries up in the course of pregnancy, so that, towards the end, there remains nothing in place, but a very small cicatrix. Is this vesicle, the outermost covering of the ovum, in which the germ is enclosed, and which is torn to allow its escape? The observations of Haller prove that the corpus luteum is formed by the remains of a vesicle that has burst at the moment of conception, and allowed the fluid it contained to escape. In a ewe opened a few minutes after coition, you may see, in one of the ovaria, a vesicle larger than the others, torn with a little wound, of which the lips are still bloody. Inflammation comes on in the torn coats of the small vesicle, fleshy granulations appear, then sink, and a scar shews the place where it had been. The number of these cicatrices is proportioned to that of the fœtuses. It is not known how long the germ detached from the ovarium remains within the fallopian tube, before it reaches the cavity of the uterus. Valisnieri and Haller had never been able to perceive it distinctly in this viscus, before the seventeenth day.

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* In extra uterine abdominal conceptions, the ovum which the tube could not hold, or seize, rolls into the hypograstic region, and there adheres to some point of the peritoneum. It is found attached to the mesentery, to the colon, to the rectum, to the external part of the uterus, growing there, and developed, by the vascular communication which takes place at the adhesion; but the vessels of the peritoneum are insufficient for the entire developement of the fœtus, which dies, for want of nourishment, in the first months of pregnancy. The adhesion of the ovum to the peritoneum, is easily accounted for, by the irritation it occasions: it may be considered as a foreign body, determining, by its presence, inflammation of the membrane, with which it lies in contact, and uniting with it, because it brings to this act, its own share of vitality. It is really a union of two living parts, not unlike that to that which takes place, between the bleeding lips of a wound, between the pleura, pulmonalis, and the pleura costalis, &c.

But as the serous membranes contain, in their tissue, capillaries so fine, that when in a healthy state, the blood does not shew its colour in them, their vessels never develope themselves, sufficiently to transmit to the ovum, which has adhered to them, a due supply of this fluid. The mucous membranes receiving more blood, are able to supply more: but the placenta never adheres to them, in extra uterine conception. The membrane which lines the tube, belongs, in fact, as much to the serous as to the mucous membranes; it establishes, as is well known, the only point of communication there is between the two kinds of membranes.

The obstruction of the tubes may, as well as the defect or diseased affection of the ovaria, cause barrenness. Morgagni speaks, on this head, of certain courtezans in whom the tubes were entirely obliterated by the thickening of their parietes; the consequence, evidently, of the habitual orgasm in which they had been kept, by too frequent excitation. The structure of these parietes must make obstructions of the fallopian tubes very easy. Their tissue is spungy, vascular and seems susceptible of erection, like the corpus cavernosum of the penis and of the clitoris. Their internal coat (the point of union between the serous membrane which lines the abdomen, and the mucous membrane within the uterus) partakes in the inflammation of both. I have often been consulted by young women on the cause of their sterility; by a close investigation of the causes from which it might have arisen, I have always found that they had had, at different periods of life, inflammation of the lower part of the abdomen. A young woman, after obstinate suppression of the menses, exhibited all the symtoms of inflammation of the peritoneum: a year afterwards she married, but never became pregnant. A woman recovered from puerperal fever, ensuing upon a very difficult first labour; from that time, with all the appearances of the stoutest health, she has never been again a mother.

Do the two testicles and the two ovaria, contain the separate germs of males and females? Are these, as has been guessed, contained in the left ovarium, and males in the right? and may we pro-create sexes at pleasures, by varying the attitude of copulation? This old opinion, lately revived, besides wanting all foundation, is formally confuted by facts: nothing is more common than to see men who have, from some accident, lost a testicle, pro-creating sexes indifferently. Women, with an ovarium deficient, or the fallopian tube obliterated on one side, have produced both boys and girls. Dr. Jadelot has presented to the society of the School of Medicine, in Paris, a uterus, wanting the right tnbe and ovarium: and nothing indicated that they had ever existed. On inquiry concerning this woman, it appeared that she had been delivered of a boy and two girls: Haller quotes similar cases. The cause, then, which determines the sex, altogether eludes our investigation. Does that one of the two, who exerts most energy in the act of coition, impress its sex on the offspring? I cannot tell; but I think I have observed that the marriage of young people, where both are glowing with love and youth, most frequently produces daughters, whilst boys are ordinarily the consequence of the union of a middle aged, or elderly man, with a younger woman.

CCVI. *Systems on generation.* The antique system of the mixture of the semen in the cavity of the uterus, set forth in the writings of Hippocrates and Galen, is still that of many physiologists. In this system, the mixed fluids may be considered as an extract from all parts of the body, male or female. A generative faculty* disposes them suitably for the formation of the new individual. Buffon has further particularised the facts which this hypothesis requires, and displayed its improbability. Each part, he says, furnishes molecules, which he calls organic, and these molecules, coming from the eyes, the ears, &c. of the man and the woman, arrange themselves round an internal mould, of which he admits the existence, which mould forms the basis of the edifice, and comes from the male probably, if it be a boy, from the female, if a girl. Reason rejects a theory which gives no explanation of the production of the placenta, and of the membranes covering the fœtus: it is moreover directly disproved by the good conformation of children, born of parents, who not happening to have certain organs and limbs, could not certainly supply the proper molecules for their formation in the child.

The system of the ovarists, which at this time stands highest in favour, numbers amongst its supporters, Harvey, Stenon, Malpighi, Valisnieri, Duhamel, Nuck, Littre, Swammerdam, Haller, Spallanzani, Bonnet, &c. These admit the distinction of animals into oviparous and viviparous, in this sense only, that these last hatch within, and break their shell before they are brought forth. Lastly, Leeuwenhoek, Hartsoeker, Boerhaave, Mery, Werheyen, Cowper, &c have added to the opinion of the ovarists, that the seed of the male contains a multitude of spermatic animalcules, all capable of becoming, by developement, beings similar to their father. These animalcules push forwards, along the tubes, upon the ovaria: there a general engagement takes place, in which all are slain, save only one, who, master of the field of battle, finds the triumph of his victory within the ovum that has been prepared for him. This system, which is not the most probable in the world, assigns to the male the greater part in the work of generation, since the female is made to furnish merely the coverings of the fœtus.

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* All that Blumenbach has said, on the force of formation, (*nisus formativus*) applies to this generative faculty; it is only a new name given to an old idea.

It would be to no purpose to unfold, more at large, opinions hazarded on a subject so obscure. What I have said is enough to shew that those parts of nature which most obstinately elude our curiosity and afford most scope to our imagination, are those which men believe they know the best, and on which they speak with most confidence and prolixity:—so true is it, as Condillac, has observed, that we have never so much to say, as when we set out from false principles.

CCVII. *Of gestation.* From the moment of conception, there begins in woman, both in the motion of the solids, and the composition of the fluids, a remarkable alteration. The change that has taken place shews itself in all her functions: she exhales a peculiar odour; the child she suckles refuses the breast, or takes it with reluctance, and soon falls away, if left in the hands of such a nurse.

Nature, occupied over her work, seems to forget every thing else, to bring it to perfection. It has been observed, that in times of contagious diseases, even where the plague raged, pregnant women were least exposed to infection: but, at the same time, when they are seized with affections, which in other persons or at another season, would be without danger, they sink under them, because these diseases, though at first very slight, easily put on a malignant character. The progress of mortal diseases is retarded: a phthisical woman, and who has only a few months to live, shall prolong her life through the whole term of gestation. The consolidation of fractures is nothing slower, though Fabricius, Hildanus, pretends that the state of pregnancy puts a complete stop to it.

I have never been able to find any difference in the time of formation of callus, between pregnant women and others. M. Boyer avows the same opinion.* Among the authors who have asserted that fractures could not consolidate during pregnancy, some have conjectured that this depends on Nature, who is busy in directing the humours to the uterus, forgetting, in some sort, every other function, and omitting to institute the process necessary to the cure. But as we shall see, whatever may be the importance of the uterus, charged, during pregnancy, with the fruit of conception, the fœtus is merely an organ added to the organs of the mother, and assimilating to itself the juices it receives from the uterine vessels. It does not hinder the other parts from getting their nourishment; they all go on living, and separating to themselves the juices their existence or their functions require. Haller ascribes the difficulty with which the broken ends unite, in pregnant women, to the great quantity of earthy matter which the fœtus draws off from the mother. This opinion will not stand; for, as I have shewn in my preliminary discourse, the phosphate of lime has but little to do in the work of re-union, which chiefly goes on by changes in that part of the bone which is really organic. Besides, this hypothesis would imply that consolidation were as difficult in nurses, whose milk carries off a large quantity of phosphate of lime. Yet it has not been observed that the formation of callus is more difficult during suckling. Lastly, on this, as on all occasions, experience is more effectual than reasoning; now, experience shews, that the time required for the formation of callus, in pregnant women, is not sensibly longer than in their ordinary state.

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* Lecons de M. Boyer, sur les Maladies des os, redigées en un Traité complet de ces Maladies, par A. Richerand, 2 vol.

Meanwhile, the uterus, imbued with prolific fluid, swells, to avail myself of the expression of a modern, like a lip stung by a bee: it becomes a centre of fluxion towards which the humours tend from all quarters. The diameter of its vessels increases with the thickness of its parietes: these soften, and their muscular nature becomes more marked. Till the end of the third month, the only appearance of pregnancy is in the suspension of menstruation; the uterus, of which the cervix has yet undergone no change, has concentrated itself behind the pubis, but very soon it rises above the upper outlet of the pelvis, pushing upwards the intestines and the rest of the abdominal viscera. Towards the end of pregnancy, it rises above the umbilicus, its fundus comes in contact with the arch of the colon, and reaches sometimes to the epigastric region. The compression it exerts on the organs of digestion, explains the loathings, and the nausea which belong to the state of pregnancy. The derangement of sensibility, by the affection of the great sympathetics, accounts equally for those depraved tastes, those fantastic appetites, which the ignorant think it so important to gratify. When the term of pregnancy draws near, respiration is oppressed, the diaphragm forced upward by the abdominal viscera, descends with difficulty; accordingly, Nature has, as much as possible, delayed this moment of oppression, by giving the lower part of the abdomen a great capacity, at the expence of the chest, which, in woman, is much shorter than in men.

If the growth of the fœtus, its size, the quantity of liquor amnii, the developement of the uterus, were always the same, we might settle the height to which this last organ must rise, at each stage of pregnancy; but these conditions vary so much, in every individual, that the terms one might assign would suit but a small number: let it suffice to have spoken of the extremes. The uterus tends to rise directly upwards; while enclosed within the pelvis, it preserves this direction; but, as soon as it has passed the upper outlet of the pelvis, it is no longer supported, and inclines forwards, backwards, or to the sides. These inclinations, if they go a certain length, constitute those vices of situation which accoucheurs call obliquities of the uterus. Their direction is determined by the disposition of the parts: accordingly, they almost always lie forwards: either because the upper outlet of the pelvis is naturally so inclined, and forms, with the horizon an angle of 45 degrees, or because the lumbar column, being convex, pushes the uterus, which cannot depress it, upon the anterior paries, which yields the easier, the more frequent pregnancy has been.

The dilatation of the uterus is not the effect of a simple distention of its parietes, since these, far from stretching thinner, as the viscus grows in size, thicken progressively, on the contrary, by the dilatation of vessels of all sorts and the afflux of humours. In this sort of vegetation, the uterus is really active, and does not give way to any efforts of the fœtus. The cervix of this viscus, which from its greater consistency, had at first resisted dilatation, ends by yielding to the efforts of the fibres of the fundus, on the edges of the os tincæ; the edges of that opening are attenuated, the cervix effaced, the orifice enlarges, and you may feel through its parietes, the fœtus plunged in the waters which its membranes contain.

Towards the term of gestation, the discharge of urine is more frequent, because the bladder, under compression, cannot contain it in any quantity? the lower extremities are œdematous; the veins of the legs varicose: women are also more exposed to hæmorrhoids; and these effects depend on the compression of the vessels, which bring back the blood and the lymph of the inferior parts, as the cramps, to which pregnant women are subject, depend on that of the sacral nerves. The groins are alike painful, and there are felt, in them, twitchings which must be ascribed to congestion in the round ligaments of the uterus. Lastly, the skin of the anterior paries of the lower part of the abdomen, distended beyond measure, cracks, when that of the neighbouring parts has yielded as much as it could.

Before explaining how the uterus expels the fœtus and its coverings, at the term of gestation, let us consider, a little, this fruit of conception: let us study its developement, let us examine the nature of the relations which it holds with its mother.

CCVIII. *History of the fœtus and its coverings.*—The interior of the uterus, for a short period after the instant of conception, shews nothing that leads to a knowledge of the existence of its product. But, at the end of a few days, there appears a membranous transparent vesicle, filled with a liquid trembling jelly; discovering no trace of organization and life. But the little ovum begins to grow, parts of the gelatinous fluid, assume more consistence, losing, at the same time, their transparency: one may then distinguish the first rudiments of parts, an imperfect appearance of the head, trunk, and limbs. The small ovum, free at first in the cavity of the uterus, contracts adhesions to this viscus: its whole exterior surface becomes shaggy, and this sort of vegetation is no where more marked, than in the situation to be occupied by the placenta. Meantime, towards the seventeenth day, the parts which shewed merely a homogeneous semi-transparent mass, discover a more determinate structure. A red point appears in the spot of the heart, it is the heart itself, distinguishable by the pulsations of its cavities, and the motions of the molecules of the red liquid that fills them. Because the heart is the punctum saliens, it is not therefore to be concluded that it is the *primum vivens.* All our parts are formed together, all are coeval, as Charles Bonnet has said; only they discover themselves earlier or later to the eye of the observer, according as the nature of their organization is adapted to the reflexion of light. Were we to admit a successive order in the formation of our organs, the brain and the nervous system might exist before the heart, without being perceptible from their transparency.

Meanwhile, red lines, setting off from the heart, sketch the course of the larger vessels, and seem agitated by the action of these tubes, whose parietes are still semi-transparent. As the blood, or rather its red part, extends from the centre to the circumference, the forms become more determinate, the parts unfold and grow rapidly: points quite opake, are seen, and the form of the fœtus may be distinguished. Bent upon itself, the fœtus is not unlike a French bean, suspended by the umbilical cord, which, as I shall mention bye and bye, formed with the fœtus and its coverings, proceeds in growth with them: it swims amidst the liquor amnii, changes its position the more easily, as the space, in which it is enclosed, is greater, compared to its size. As it grows, it stretches out a little, without ceasing however to retain its bent posture (CLXV): the head composes the greater part of its body: the upper limbs, like little buds, pullulate first, then the lower limbs: the feet and the hands appear immediately attached to the trunk; the fingers and toes shew themselves like little papillæ. Of all the organs of sense, the eyes are the first apparent: they are discernible, as two little black spots, by the end of the first month; the eyelids are produced and cover them. The mouth, at first gaping, closes by the drawing together of the lips, towards the end of the third month. During the fourth, a reddish coloured fat begins to be deposited in the cells of the mucous tissue, and the muscles already exert some action. The growth is ever more rapid, as the fœtus draws nearer to its birth. It is impossible to assign the weight and the length of the fœtus, at the different stages of pregnancy, since the time of conception is never very certain, and further, the progress of growth varying much, one fœtus at six months shall be as large as another at the full term. Nevertheless, at the time of birth, the body is commonly 18 inches long, and weighs from seven to eight pounds.

The secretion of bile, like that of the fat, seems to begin, towards the middle of gestation, and tinges the meconium yellow, a mucus previously colourless, which fills the digestive tube: a little while after, the hairs grow, the nails are formed about the sixth or seventh month; a very thin membrane, which closed the pupil, tears, by what mechanism is unknown, and the pupil is seen. The kidneys, at first manifold, that is to say, formed each of from 17 to 18 separate glandular lobules, unite, and form, on each side, a single viscus. Lastly, the testicles, placed at first, at the side of the lumbar column, and aorta, near the origin of the spermatic arteries and veins, then carried along the iliac vessels to the inguinal rings, directed by a cellular cord, which Hunter calls the (*gubernaculum testis*,) clear this opening, carrying along with them the portion of the peritoneum which is to form their tunica vaginalis.

This covering of the testicles, furnished by the peritoneum, not only covers these organs, and is reflected again over them, but also rises, in adults, about half an inch high, along the lower part of the spermatic cord. If it do not reach, it is said, to the inguinal ring, it is because the whole portion which, after birth, extended from this opening to near the testicle, has been decomposed, and is reduced to cellular tissue. Upon reflecting on the causes of the spontaneous decomposition of a portion of this peritoneal prolongation, it occurred to me, that nothing was less proved, or more improbable; in fact, in earliest life, the testicles, which have passed out from the abdomen, by the inguinal rings, are very little removed from this opening. The portion of tunica vaginalis, which is carried on upon the cord of the spermatic vessels, rises up to the ring, and even extends beyond it, communicating with the peritoneum, as is sometimes seen in congenital bubonocele. It is only in the progress of life, that the testicles descend into the scrotum, still departing from the opening which gave them passage: so that, in adults, the prolongation, which at first covered the whole cord; which, just after birth, was not more than a few lines long, is found to cover only its lower part, when it is lengthened some inches, without any necessity of decomposition; a phenomenon, which it is as difficult to conceive as to explain. This opinion, suggested, for the first time, in the first edition of this work, is now almost universally received.

CCIX. *Of the circulation in the fœtus.* The principal difference that is found between the fœtus and the new-born child, besides the inactivity of the senses, and the repose of the muscles subject to volition, lies in the manner in which the circulation is carried on. Too feeble to assimilate to its own substance foreign substances, the fœtus receives from its mother aliments ready prepared. The arteries of the uterus receive a large supply of blood; this is not all employed for the nourishment of the organ itself, but passes, in great part, from the mother to the child, being poured, by the uterine vessels, into the cells of a spungy substance, adhering on one side to the uterus, and on the other to the ovum which contains the fœtus.

This cellulo-vascular body, known under the name of placenta, is, as well as the coverings of the fœtus and the fœtus itself, a product of the act of generation. Though it adheres commonly to the fundus of the uterus, it may adhere to any other point of its parietes; sometimes, even, it is placed on its orifice, a circumstance which always makes delivery difficult. The side by which it is united to the internal face of the uterus, is uneven, covered with mammillary projections (*cotyledons*), which are sunk in corresponding cells of the parietes of the uterus, the internal surface of which, loses, as it developes itself, the smoothness which it had while empty, is furrowed with depressions destined to receive the placenta, and studded with projections which penetrate into the cells of the latter.

The uterine arteries, and perhaps likewise the absorbents which are so large and numerous in the gravid uterus, that Cruickshank, who succeeded in injecting them, compares them to quills, throw out, on the surface of the placenta, and within its spungy tissue, the arterial blood of the mother; according to some, these vessels exhale only the serous part of the blood, and according to others, a chylous, lymphatic, whitish, or milky substance.* These fluids, effused within the cells of the placenta, are absorbed by the numerous minute divisions of the umbilical vein, which, by their union, form the trunk of this vessel.

The umbilical vein, arising from the interior of the placenta, by numerous branches, detaches itself from it and goes towards the umbilicus of the child, enters his body, at that aperture, ascends, in a fold of the peritoneum, behind the recti muscles, to the anterior extremity of the sulcus of the liver, goes along the anterior half of this fissure, sending a number of branches to the lobes of that viscus, especially to the left lobe. On reaching the right extremity of the transverse fissure, where this last meets the antero-posterior, it unites, in part, with the sinus of the vena portæ hepatica, while the remainder of the vessel, called ductus venosus, follows the original direction, and opens into the ascending or inferior vena cava, very near to the spot where this vein pours its contents into the right auricle of the heart.

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* A German physician, Schreger, has suggested a very ingenious opinion on the mode of circulation, between the mother and child. He believes that the uterine arteries pour out nothing but serum, into the cells of the placenta. This serum is absorbed by the lymphatics, whose existence he infers from analogy, in this organ and in the umbilical cord, in which, however, no one has yet succeeded in injecting them. These vessels convey it to the thoracic duct, whence it is poured into the left subclavian vein and, at last, reaches the heart which sends it along the aorta. It returns to the placenta by the umbilical arteries, after being converted into. blood, by the action of the organs of the fœtus. This serosity, after undergoing the process of sanguification, returns to the fœtus by the umbilical vein, and following the well known course of the fœtal circulation, is subservient to the nourishment of its organs. The branches of the umbilical arteries and vein, ramified in the placenta and communicating together in this spungy tissue, reject through their lateral pores that which can no longer serve to the maintenance of the fœtus. This residue of nutrition, deposited in the cells of the placenta, is absorbed by the lymphatics of the uterus, which carry it back into the mass of the fluids of the mother. Not to mention

CCX. The arterial blood which flows along the umbilical vein, acquires the properties of venous blood, and combines with hydrogen and carbon, and parts with its vivifying qualities, in flowing along the vessels of the mother and the tortuous vessels of the placenta. It parts with these principles, and again becomes vivified, by circulating through the liver which, at this period of life, fulfils the function which, after birth, is committed to the lungs. Hence the liver and brain form the greatest part of the weight of a new born child. The former alone occupies the greatest part of the abdomen. It acquires this bulk, by assimilating to itself, the hydrogen and carbon of the umbilical blood. Its substance is adipose, oily, and contains these two principles, in a considerable proportion. The secretion of the bile and that of the fat, the only secretions that are manifestly carried on in the fœtus, may besides supply, very well, the want of respiration.

The blood conveyed by the umbilical vein into the lower vena cava, and deposited by that vein into the right auricle, does not unite with that which is brought by the descending cava, from the upper parts, for, as was observed elsewhere, the orifices of these two vessels not being directly opposed to each other, the columns

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the impossibility of demonstrating the presence of lymphatics, in the placenta, or in the umbilical cord, Schreger's hypothesis is attended with two objections. How does the nutritious fluid, coming from the mother and sent along the aorta of the fœtus to every part of its body, return to the placenta, to be brought back again by the umbilical vein? Absorption scarcely goes on in the fœtus: the unctuous substance with which the body of the fœtus is covered, prevents that function from taking place on the surface of the body. It goes on, with very little more activity, within the body; the excrementitious secretions scarcely exist before birth; whatever is conveyed to the fœtus is employed in the developement of its organs; hence its growth is so rapid.

of blood which flow in them do not meet each other. That which is brought by the lower cava, passes through the foramen ovale, towards which the mouth of that vessel is turned; it passes into the left auricle, thence into the left ventricle, without circulating through the lungs, which containing no air and being dense and indurated, could not have received it; the contractions of the left ventricle send it into the aorta, the force of its impetus is broken, by striking against the great arch of this artery. It enters into the vessels which arise from it, and these convey it directly to the brain and upper parts. This blood is the most pure, the most oxygenated, and that which comes most immediately from the placenta; it has not yet circulated in the body of the fœtus, with the exception of a very small quantity brought from the pelvis and lower parts, for, the blood which comes from the abdominal viscera, is purified in passing through the liver. The other parts of the body receive, on the contrary, blood very imperfectly oxygenated, since the very inconsiderable quantity which the contractions of the left ventricle and of the aorta have not been able to send into the vessels arising from the arch of this vessel, mixes with the venous blood which is brought by the ductus arteriosus, immediately below this curvature. Hence the growth, which is always relative, not only in respect to the quantity, but likewise to the vivifying qualities of arterial blood, is much more rapid, before birth, in the upper parts, so that the brain alone constitutes the greatest part of the body, and the shoulders, the chest and the upper extremities are developed, in a much greater degree than the abdomen, and especially than the pelvis and lower extremities.

The blood which is brought by the descending cava, from the upper parts of the body of the fœtus, passes into the right ventricle which forces it into the pulmonary artery; this vessel sends only two small branches to the lungs, and terminates, by a vessel called the ductus arteriosus, into the aorta, immediately below the origin of the left subclavian artery. The aorta, at its origin, is therefore filled with arterial blood, sent towards the upper parts of the body, by the contraction of the left ventricle, while the remainder of this artery contains venous blood, which is expelled by the combined action of both ventricles.

It is impossible, in this arrangement, not to recognize an evident design. In fact, if the whole force of the heart had been exerted to send the blood towards the brain, the delicate texture of this viscus would have been injured by it; the combined action of the two ventricles was, on the contrary, required, to enable the blood to circulate, along the extensive and tortuous channels of the umbilical cord and placenta. The aorta, on reaching the body of the fourth or fifth lumbar vertebra, divides into the two umbilical arteries; these send to the pelvis and to the lower parts, only very insignificant branches, which convey blood that contains a very small quantity of oxygen; they then bend along the sides of the bladder, incline inwards, approach towards the urachus, pass out of the abdomen, at the umbilicus, and joining the umbilical vein which had entered, through the same opening, into the body of the fœtus, form with it, the umbilical cord.

CCXI. The length of the umbilical cord, measured from the umbilicus to the placenta, is from twenty to twenty-four inches. It may be not above six inches long, or may greatly exceed that length, as is proved by a case of M. Baudelocque, in which the umbilical cord was fifty-seven inches in length, and passed seven times round the child's neck, which circumstance, by the way, shews that the fœtus moves in its mother's womb. Of the three vessels which form the umbilical cord, two, which are the smallest, have an arterial structure, though they convey blood that is truly venous, while the umbilical vein carries arterial blood to the fœtus. The umbilical arteries, on reaching the placenta, divide and are lost in its substance, in a multitude of vessels whose extremities deposit, into the areolæ of its tissue, the blood coming from the fœtus, and which is to be returned to the mother. Does the course of injection, from the umbilical vein into the arteries, prove that there exists an anastomosis between the extremities of these vessels?

The fœtus is connected to the mother, by the umbilical cord and placenta; the veins, or the lymphatics of the uterus, and perhaps both these sets of vessels, take up, in the spungy tissue of the placenta, the blood that has been employed in the nutrition of the fœtus, and return it to the mother, that, after undergoing a change by the action of her organs, and especially by that of the atmospherical air, by means of the pulmonary circulation, it may become fit for the nourishment of the fœtus. Whether we inject the uterine vessels, or whether we force the wax along the umbilical vein, it never fills but a part of the placenta, which has led to the division of this substance into two parts, the one belonging to the mother, which has been called uterine, the other, called the fœtal portion, which forms a part of the umbilical cord.

The vessels of the mother do not, therefore, anastomose with those of the fœtus within the placenta, the circulation is not continued from the one to the other. If the communication were immediate, the beats of the pulse of the child, ought to be simultaneous with those of the mother, whereas they are much more frequent, as may be observed, at the time of birth, before the division of the umbilical cord. If the veins of a bitch, ready to whelp, are opened, the animal dies of hemorrhage, and her body remains bloodless. The placenta, however, is empty, only in the part that adheres to the uterus, the rest of the placenta, as well as the fœtus, are filled with blood, as usual. It is obvious, that if the vessels of the uterus had been directly continuous with those of the placenta, delivery would not have taken place, without their being torn, alarming hemorrhage, inflammation, and even suppuration of the uterus would have been the consequence. Lastly, the force with which the heart and arteries of the mother, impel the blood along her vessels, would have been attended with danger to the organs of the fœtus, which are too soft to sustain, without injury, so violent a shock. Though the placenta and the umbilical cord form the bond of union between the fœtus and the mother, it must be confessed, that they belong chiefly to the former, and may be considered as a continuation of its body.

CCXII. The existence of the fœtus is solely vegetative; he is continually drawing from the juices, which the vessels of the mother send to the placenta, what is to serve to his nourishment and growth. He may be considered as a new organ, the product of conception, participating in general life, but having a peculiar life, and, to a certain degree, independent of that of the mother. Bent on himself, so as to occupy the least possible space, he cannot be considered as asleep; for, not only are the organs of sense and of motion in a perfectly quiescent state, but besides, several of the functions of assimilation are inactive, as digestion, respiration, and most of the secretions. The fœtus performs, in the midst of the liquor amnii, spontaneous motions, which accoucheurs reckon among the signs of pregnancy. The existence of these phenomena has been denied, and the displacement of the fœtus has been ascribed to a mere shaking of the body; this was asserted on the ground of the intimate connexion between respiration and muscular motion. It was said, that the blood of the fœtus, not being impregnated with oxygen, in its passage through the lungs, contractility would not exist. But besides that a fact may be certain, without being easily explained, it may be answered, that the mother fulfills this office for the fœtus, and sends it arterial blood, fitted to maintain the contractility of the muscles.

As we perform no motion, but in virtue of impressions previously received, and as the organs of sense, in the fœtus, are completely inactive, it is not easy to say, why it should move in the womb. The touch, however, is exerted, when any part of the surface of the body of the fœtus comes in contact with the internal part of the cavity in which it is contained. Lastly, the internal impressions experienced by the great sympathetics, may act as an occasional cause of such motions.

The fœtus is nourished, like every other organ, by appropriating to itself, whatever is suited to its nature, in the blood brought to it, by the vessels of the uterus. The interception of this fluid, by a ligature, or by compression of the umbilical cord, would occasion death, though not, as has been imagined, by a sudden and quick suffocation, but the action of the organs would become gradually weakened, and at last cease, when the fluids of the fœtus, being no longer vivified by the mixture of new juices from the mother, would be completely deprived of their nutritive parts. It is now well ascertained, that the liquor amnii does not serve to the nutrition of the fœtus, whose mouth is closed, whose head is bent on his breast, and whose intestinal canal is filled with a fluid different from that in which the whole body is immersed. Besides, may not the unctuous substance with which the surface of the skin is covered, prevent the absorption which might otherwise take place, from the outer part of the body?

It was long believed that the fœtus was in an upright position, during the first months of life, but that, towards the end of pregnancy, it fell into a different position and lay with its head downwards. This erroneous opinion, believed from its antiquity, and because it was admitted by several physiologists, is completely refuted in Professor Baudelocque's work on midwifery. The absurdity of this hypothesis is manifest, if it be considered that the head of the embryo, the most bulky and weighty part of the body, must necessarily occupy the most depending part.

The plumpness and the strength of the fœtus do not altogether depend on the strength of the mother. Corpulent and strong women often bring forth puny children, while others who are thin and feeble, bring forth children plump and healthy. Such instances, however, are exceptions to the general rule, as, cæteris paribus, the healthy state of the fœtus is to be estimated by that of the mother. The morbid condition of the fluids of the mother has a considerable influence on the health of the fœtus, and is perhaps the way in which hereditary diseases are transmitted, which, by others, are ascribed to a diseased state of the semen.

The fœtus is subject to affections of various kinds, whether of spontaneous origin or arising from a germ received from the mother. Fœtuses have been seen with cicatrices, which clearly shewed, that solutions of continuity, of various kinds, had taken place. A child, born with the loss of some limb, has met with the accident, in consequence of some affection experienced in the womb. Professor Chaussier having been called in to a case of this kind, found the hand and a portion of the fore-arm, among the membranes.

CCXIII. *Of monsters.* As it is useful to study Nature, even in her irregularities, I shall say a few words on the subject of monsters, adopting the arrangement proposed by Buffon, of dividing them into three classes: the first including monsters from excess; the second, monsters from defect; the third including those in which there is a misplacement of organs. In the first, are included those which have supernumerary limbs or fingers, or even two bodies joined in various ways. In the second, children born with a hare-lip, or who are deficient in some one part. In the last place, those monsters belong to the third class, in which there is a general transposition of organs; when, for example, the heart, the spleen and the sigmoid flexure of the colon are on the right side, and the liver and cæcum on the left; those born with herniæ of different kinds, likewise belong to this class. One may reckon among these monstrous conformations, spots in the skin, the colour of which always resembles that of some of our fluids, but whose various forms are purely accidental, though, from prejudice, one is apt to imagine some likeness to objects longed for by pregnant women accustomed to those fantastic appetites and longings, so frequent during pregnancy.

Various attempts have been made to account for these unnatural formations: some, as Mallebranche, attributed them to the influence of the mother's imagination on the fœtus in the womb; others, as Maupertuis, thought that her passions communicated to her humours irregular motions, which, acting with violence on the delicate body of the embryo, disturbed its structure. Disease, while the child is in utero, is a much more probable cause of such affections.

If two fœtuses, contained in one ovum, lie back to back, and if the surfaces at which they are in contact, become affected with inflammation, it is easy to conceive that adhesion may take place between them. By placing, in a confined vessel, the fecundated ova of a tench or any other fish, the numerous young ones, which are formed, not having space sufficient for their growth, adhere to each other, and fishes truly monstrous in their formation, are produced.

When, from disease, or from an original malformation, the body of the fœtus is deficient in some of its parts, the others are better nourished and grow to a large size. Hence, in acephalous monsters, as there is no brain, the blood which should be sent to that viscus, going to the face, it acquires a remarkable enlargement.

One of the most curious of all the cases of monstrosities depending on an original defect in the organization of the germs, is that which was sent, a few years ago, by the Minister of the Interior, to the School of Medicine at Paris. I shall give an abstract of it, from a more detailed account, drawn up with much accuracy and sagacity by M. Dupuytren.

A young man, thirteen years of age, had complained, from his earliest infancy, of pain in the left side and lower part of the abdomen. This side had been prominent and contained a tumour, from the earliest period of life. At the age of thirteen, he was seized with fever, the tumour increased in bulk, and became very painful. Some days after, he voided, by stool, purulent and fetid matters; at the end of three months, he became wasted by marasmus, he passed, by stool, a ball of hairs, and, in the course of a few weeks, died of consumption.

On opening his body, there was found, in a cavity in contact with the transverse arch of the colon, and communicating with it, some balls of hairs and an organized mass. The cyst, situated in the transverse mesocolon, near the colon, and externally to the digestive canal, communicated with the intestine. But this communication was recent and accidental, and one could plainly see the remains of the septum between these cavities. The organized mass presented, in its forms, a great number of features of resemblance with the human fœtus, and, on dissection, no doubt could be entertained of its nature. There was discovered in it, the trace of some of the organs of sense, a brain, a spinal marrow, very large nerves, muscles converted into a sort of fibrous matter, a skeleton consisting of a vertebral column, a head and pelvis, and limbs in an imperfect state; lastly, a very short umbilical cord attached to the transverse mesocolon, at the outer part of the intestine, an artery and vein, ramifying at each of their extremities, where they were in contact with the fœtus and with the individual which contained it. This much is sufficient to establish the distinct existence, as an individual, of this organized mass, though, in other respects, destitute of organs of digestion, of respiration, of the secretion of urine, and of generation. The absence, however, of a great number of the organs necessary to the maintenance of life, should make it be considered as one of those monstrous fœtuses, not destined to live beyond the moment of birth. This fœtus was evidently contemporary with the boy to whose body it was attached. Similar to the product of extra uterine conceptions, it received its nourishment from that which may be considered as its brother, and whose germ had originally enclosed its own. During the thirteen years of the life of Bissieu (this was the name of the subject of this singular case), the organized mass obtained from the mesocolon, by means of vessels of its own, the blood necessary for its existence; this blood, propelled by the organs of circulation into the body of the fœtus, returned afterwards to the mesocolon of the boy who had so long been to him as a mother. At last, the period fixed by Nature, for expulsion, being arrived, and this expulsion being impracticable, the cyst became inflamed; the inflammation extended to the intestine, the part which separated these two cavities was destroyed, and the cyst opened into the colon; pus and hairs were voided by stool, and the patient died of marasmus. The drawings of different parts of the body of this fœtus, taken by M. Cuvier and M. Jadelot render this interesting case most complete. They will be published in the first volume of the transactions of the Academical Society, near the Faculty of Medicine at Paris*.

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* Mr. Young, of London, has communicated a case of the same kind, in a valuable paper inserted in the first volume of the Medico Chirurgical Transactions. In Mr. Young's case, the fœtus was contained in a cyst that seemed to answer the purpose of membranes and placenta; it was without a brain, but had imperfectly formed digestive organs and external organs of generation.

See vol. 1st of the Medico Chirurgical Transactions. T.

We ought not to be too ready to place implicit confidence in the extraordinary stories contained in the older writers, and even in some of the moderns. In reading the periodical publications of the seventeenth, and even of the eighteenth century, one is apt to wonder at the marvellous things which they contain. Among other strange cases, is that of a girl that was born with a pig's head; another of a woman who was delivered of an animal, in every respect, like a pike. There was a time, says a philosopher, when philosophy consisted merely in seeing prodigies in nature.

CCXIV. *Of the coverings of the fœtus.* The name of after-birth is given to the envelopes of the fœtus, because they are not expelled from the uterus, till after the birth of the child. The ovoid sac, which contains the fœtus, is formed by two membranes in contact with each other. The name of chorion is given to that which, by its external and shaggy surface, adheres to the inside of the uterus: the other, a concentric membrane to the former, but of less thickness, and to be considered as the secretory organ of the fluid which fills the ovum, is called the amnion. The third envelope, admitted by Hunter, and called by that physiologist, the membrana decidua, is nothing more than the lanuginous tissue presented by the external part of the chorion, after tearing the multitude of cellular and vascular filaments, by means of which the ovum adheres to the uterus. The placenta is itself merely a thicker portion of nearly the same tissue, in which the umbilical vessels are ramified. The uterus is also thicker at the part which corresponds to the placenta, because it is there that the communication of the fœtus with the mother is established.

The liquor amnii is a serous fluid, of a sweetish odour, of insipid taste, rendered slightly turbid by a milky substance which it holds suspended, and somewhat heavier than distilled water, 1,004. It is almost completely aqueous; albumine, soda, muriate of soda and phosphate of lime, discovered in it by M. M. Buniva and Vauquelin, forming only 0,012 of the whole mass. It turns of a green colour, tincture of violets, and reddens that of turnsol; a very remarkable circumstance, as is observed by the last mentioned philosophers, and indicating the co-existence of an alkali and of an acid in a separate state. The latter is, in so small a quantity, so volatile, and so soluble in the liquor amnii of woman, that it has never yet been obtained by itself; there is found, however, in the liquor amnii of the cow, a peculiar acid, called by M. M, Buniva and Vauquelin, the amniotic acid. The liquor amnii is in greater quantity, in proportion to the size of the fœtus, according as the latter is nearer the period of its formation. It is the product of arterial exhalation. Its materials are supplied by the blood conveyed by the vessels of the uterus. This is proved, not merely by analogy, but likewise by observing the connection between the qualities of the liquor amnii and the regimen of the mother. In a woman who had used mercurial friction, in the course of her pregnancy, the liquor amnii was observed to whiten copper.

The fundus of the bladder, in quadrupeds, is continuous with a canal, of which the rudiments are observed in man, and which is called the urachus. This canal joins the umbilical vessels, passes out with them, at the umbilicus, and terminates in a membranous sac, between the chorion and the amnion; it is called the allantois; it is always found in the fœtus of the lower animals, but it is very indistinct, and often does not exist in man. Some anatomists say they have seen the urachus arising from the human bladder, and which is commonly ligamentous, terminate in a small vesicle which some of them compare to a melon seed; while others say its bulk does not exceed a millet or hemp seed. So small a vesicle can certainly answer no purpose; the urachus always forming a solid cord, seldom pervious, and even of very small bore, in the part nearest the fundus of the bladder. The existence of these parts furnishes an additional proof of what was stated in speaking of the uses of the valve of the cœcum, viz. that there are in the animal body, organs which answer no purpose, and which merely indicate the plan which Nature has followed in the reproduction of beings, and the gradations which she has uniformly observed in the divisions of the species.

CCXV. *Of the natural term of gestation.* The fœtus may exist without the maternal influence, when arrived at the period of seven or eight months from the instant of conception. All accoucheurs agree that it may be delivered alive, at this period, and that it stays two months longer in the uterus, only that it may gain more strength, and be better fitted to resist the new impressions which it is to experience, on coming into the world. A child, however, has been known to live, though born at the sixth month of pregnancy, in premature labour; but, in general, the child is the more likely to live when born at the usual period; that is, towards the end of the ninth solar month, or of the tenth lunar. It is observed, that children born at seven months, however robust they may prove afterwards, are very feeble when born, have their eyes closed, and are in a state of extreme debility and suffering, during the two months which they ought to have spent in their mother's womb; this proves how necessary it is that gestation should be carried on to the end of the ninth solar month.

If the fœtus may live, though separated from its mother, before the natural period, may it not, likewise, remain longer within the womb, grow with less rapidity, and be expelled some days, weeks, and even months later? How difficult therefore will it not be to assign a precise term, beyond which we shall not be able to admit the possibility of a late birth!

There are said to be authentic cases of children born more than ten months after conception; yet the laws, which cannot be founded on rare exceptions, do not allow of so long a period in deciding of the legitimacy of children born after the dissolution of matrimony.

CCXVI. *Of parturition.* When the fœtus has remained sufficiently long within its mother's womb, to acquire the degree of strength required for its insulated existence, it becomes separated from her, carrying along with it the parts which enclosed it, and by which it was connected to the uterus. Its expulsion from the uterus is called delivery. The most ridiculous opinions have been entertained, with regard to the causes which determine the coming on of labour; according to some, Fabricius of Aquapendente, for instance, it is the want of fresh air, which makes the fœtus rupture its membranes; according to others, the fœtus is determined to the same process, by the necessity of voiding the meconium, an excrementitious fluid, which fills the intestinal canal. It has been said, that the fœtus was urged to it, by the want of food, or that labour depends on the re-action of the fibres of the uterus, which, distended beyond measure, towards the end of pregnancy, close on themselves, and overcome the resistance of the cervix uteri, which is thinned and gradually dilated. But, if this last hypothesis be correct, and it is the only one that is, at present, in any esteem, how comes it, that in a woman, whose uterus is of a determinate size, labour does not come on, when there are twins, at the end of four months and a half, by which period, the same degree of distention would be produced, as by one child at the full time.

It is very true, that for a fortnight, and even sometimes for a month, before labour, the uterus seems to be preparing for the expulsion of the fœtus. This, at least, may be inferred from the prominence of the cervix of the uterus, which may then, sometimes, be felt; and which is evidently produced by the membranes containing the waters, which insinuate themselves within the orifice of the uterus, when this organ contracts, and which collapse and recede, when the uterus is relaxed.

The product of conception, after a certain time, reaches a period at which it may exist, separated from the mother. When this period is arrived, the ovum in which it is contained, detaches itself from the uterus, by a mechanism, in every respect, similar to that, by which the stalk of a ripe fruit drops from the bough on which it hung. Then, in all probability, the fœtus refuses to admit the blood sent to it by the umbilical vein. The placenta becomes affected with congestion; this stagnation of the fluids extends, gradually, to the uterus, and to the neighbouring parts. Stimulated by their presence, these organs are called into action, the woman feels wandering, irregular pains, similar to cholic pains, which become more acute, are attended with a feeling of constriction, and act from above downwards, that is, from the fundus, to the cervix of the uterus.—This contractile cavity, assisted by the diaphragm and abdominal muscles, then acts with redoubled effort to expel its contents. The pains become more acute and frequent; the face red, the pulse full and frequent, the whole body seems to partake in the affection of the uterus, and is agitated with convulsive motions. The membranes, filled with the waters, force themselves like a wedge, through the mouth of the uterus, whose edges are much weakened; the throes of labour increase in strength and number, the membranes rupture, the liquor amnii escapes, the head of the child follows, and it soon clears the mouth of the uterus with most excruciating pains.

These pains are particularly severe, when the sacrum not being sufficiently concave, the nerves of the sacral plexus are violently compressed by the head of the fœtus; this part of the body, almost always, presents first; it passes through the upper outlet of the pelvis, in an oblique direction, the occiput being turned forward, and corresponding to one of the acetabula, while the face is directed backward towards one of the sacro-iliac junctions. It passes thus along the greatest diameter of the pelvis, but in descending lower down in the pelvis, it describes a portion of a circle, and passes through the lower outlet of the pelvis, at its greatest diameter, which is from the fore to the back part. The head descends through the vagina, appears outwardly, soon disengages itself, and is followed by the shoulders and the rest of the body. Thus it is, that Nature, after having produced fecundation by an act attended with pleasure, expels the product of conception in the midst of pain.

CCXVII. The passages, along which the fœtus is carried out of the body, would be too confined, in their ordinary state, to allow expulsion to take place without laceration, if, as I am going to explain, Nature had not disposed every thing to facilitate labour. In fact, Nature has not only formed the fœtal skull of several flexible pieces, separated by membranous unossified spaces, so as to allow the bones to move over one another, and the whole head to be reduced in size, in passing through the female pelvis, but she has, besides, united the bones of the pelvis, in such a manner, that their articulations become evidently relaxed, towards the end of pregnancy. During the progress of pregnancy, the fluids of the mother flow, in every direction, towards the pelvis and the parts which it contains; the ligamento-cartilaginous articulations of the pubis, of the sacrum and loccyx, soaked in fluids, unite, with less firmness, the bones between which they are placed. Hence, being softened and swollen, they do not force them asunder, like a wedge, by increasing the diameters, but facilitate the separation of the bones, by the passage of the head through the pelvis. It is on the relaxation of the articulations of the pelvis, that the indication for the operation of dividing the symphysis pubis, rests; an operation performed successfully by Sigault and by Professor Alphonse Leroy. Analogy led very naturally to this operation, as is judiciously observed by M. Thouret, in the same manner that the invention and application of the forceps were founded on a consideration of the means employed by Nature, to lessen the bulk of the child's head, during the progress of labour.

The foresight of Nature is not limited to the facilitating the motion, on one another, of the osseous parts of the skull of the fœtus, and of the pelvis of the mother; her care extends to the soft parts of the latter; these are soaked in mucus, so as to relax their tissue several days before parturition, and are so disposed, as was already observed (CCI), that they may, without rupture or violence, and by the mere unfolding of the folds of the skin, yield to a considerable degree. As the placenta and the membranes are not expelled, immediately after the fœtus, it is customary to separate them, by dividing the umbilical cord, near the navel. It is unnecessary to tie this cord, at the part near the mother, every communication being intercepted between the placenta and the uterus, so that no blood could flow but that of the placenta. Not so, however, with the part nearest the fœtus; though the changes which take place, in the circulation, at the moment when the chest is dilated, and allows the air to distend the pulmonary tissue, divert the blood from the umbilical vessels; these changes, however, in the circulation of the fluids, might come on slowly, from the weakness of the new born child; hence it is always prudent to prevent, by a ligature, a loss of blood that would increase the debility.

The human ovum is very seldom detached entire, and never so without considerable danger; that is, the fœtus is not expelled with its membranes and in the liquor amnii, for these are not, in general, expelled till a quarter of an hour, half an hour, or even a full hour after the delivery of the fœtus. When the uterus is completely emptied, its cavity becomes obliterated by the approximation of its sides; this organ, contracted on itself, sinks behind the pubis, its cervix closes and this even impedes the delivery of the after-birth, when the latter is protracted too long. The parietes of the uterus, imbued with fluids are thicker, than in their natural condition; but they decrease in size, in consequence of the lochial discharge, and return to their wonted thickness.

When the labour is over, the uterus falls, as it were, asleep, and enjoys repose, after painful exertion. The humours cease to be determined to that organ, towards which they are no longer directed, by any irritation, and they flow towards the mammary glands, to supply the secretion of the fluid which is to nourish the new-born child.

CCXVIII. *Of twins.* Though, in the human subject, the offspring is generally single, it is not uncommon for a woman to bring forth two children at once; it has even been calculated, that the proportion of twin cases to single births, was as one to eighty. Indeed, there are cases of women who have brought three children, at a birth. Haller calculates that the number of these last, to those of single births, is as one to seven thousand. The cases of four children at a birth, are still less frequent, and if three children born at once, seldom live long, the others, which, when born, are of the size of children at five months, cannot live. Only one or two instances are known of five children, having been born at a birth; Haller, therefore, is guilty of exaggeration, in saying that these cases are to the ordinary cases, in the proportion of one to a million. I take no notice of the instances in which a greater number are said to have been delivered at once, because those cases are not well authenticated. In the case of twins, each child has its own umbilical cord, terminating, sometimes, in a separate, and sometimes in a single placenta. Both fœtuses are enveloped in one chorion, but each has a distinct amnion, and floats in a separate liquor amnii. It would be curious to know, whether in women who have had twins, as well as in animals, one should find two cicatriculæ, both in the same ovarium, or one in each. Twins are, generally, very like one another, in features and dispositions.

The multiplicity of fœtuses, in the same pregnancy, is occasioned by the presence of several vesiculæ, ready to be detached from the ovaria, and consequently ripe for fecundation. This multiplicity of offspring contributes very little to increase population, for, they are, in general, less robust and strong, and not so capable of reproduction; they, besides, exhaust the strength of the mother, and their birth is often fatal to her. The number of children which a woman might bring into the world, from the period of puberty to the cessation of the menstrual discharge, would be much greater than it generally is, if no time were lost. Some women have been known to have twenty-four, thirty, thirty-nine, and even fifty-three children. A woman died in North America, after having had five hundred children and grand children, of whom two hundred and five survived her.

It is now well known, that the number of male children who are born, exceeds, in general, that of the females. The difference, in some countries, is estimated at one in twenty one, at a fourteenth, a twelfth, and sometimes, though rarely, at a third. In all countries of the world, polygamy is, therefore, in direct opposition to the intentions of Nature, and to the multiplication of the species; this is proved, in a most undeniable manner, by the loss of population in those countries in which this practice exists. The boys, more numerous than the girls, during the early part of life, exposed afterwards, to the dangers of war, of navigation, and occupied in laborious occupations, lead a more laborious and anxious life, and die in greater numbers, so that the eqilibrium is soon restored, and the least numerous portion of the human species, at the cradle, forms about two thirds of it, in old age, since we always see more women than men reach a very advanced age.

CCXIX. *Of superfœtations.* The cases of fœtuses born with unequal degrees of developement, are not to be considered as superfœtations, but as twin cases. Thus, if, in a case of twins, one fœtus is of its full size, while the other is an embryo whose size does not exceed that of a fœtus in the first month; it does not follow that their conception took place, at different and distant periods, but merely that for some reason or other, one of the germs has been incapable of growth and developement.

To settle the question of superfœtations, one should know whether a woman, with a single uterus, is capable of conceiving, two months after effective copulation. Haller is of opinion, that the cervix of the uterus is always open to the semen; but how is the latter to reach the ovaria, through the adhesions of the chorion to the uterus? It appears easier, where the two conceptions are separated by a short interval; thus, the American woman mentioned by Buffon, who, in the course of one morning, had connexion with her husband and with a negro slave, bore two children of different colours. Hence, likewise, it sometimes happens, that one of two twins is, by its features, a living testimony of adultery.

Two children, born with an interval of some months between their births, cannot be considered as twins, though they may have existed some time together within the mother's womb. The possibility of such superfœtations is well proved; they are ascribed to septa, dividing the uterus, sometimes, into two cavities, merely because such an arrangement would explain, to a certain degree, how two conceptions might take place, at some interval from one another; for it has never been ascertained, by actual dissection, that any woman, in whom such superfœtations took place, had a double uterus.

CCXX. *Of suckling.* Nothing is more generally known, in physiology, than the strict sympathy which subsits between the uterus and mammæ; a connexion, in consequence of which, these two organs are called into action, at the same period of life, are evolved, and cease to perform their functions, at the same time, when woman becomes incapable of co-operating in the reproduction of the species. I shall not endeavour to account for this sympathy, by ascribing it to the influence of the nervous system, or to the anastomosis of the epigastric with the internal mammary arteries; an anastomosis which is not uniform, for, instead of inosculating with each other, these vessels frequently terminate in the recti muscles of the abdomen. But even though this anastomosis should exist, as distinctly as it is often met with in some subjects, it would not account for this sympathy, since the uterus and the mammæ often receive no branches from the epigastric and mammary arteries, and when they do they are exceedingly small.

The new born child, on being brought in contact with the breasts, applies his mouth to the nipple, and withdrawing his tongue, while, with his lips, he compresses the edges of the nipple, he draws in the fluid whose flow is facilitated by the erection of the lactiferous tubes. These ducts, from twelve to fifteen in number, not only become enlarged, when the nipple, which almost entirely consists of them, is elongated by being drawn out by the child, but, besides, being excited by hi touch, they become affected with a certain degree of erection, and emit their fluid. This excretion, like that of other glands, is excited by the touch and the motion of the hands of the child on his nurse's breasts. The use of these gentle compressions, is not so much to express the milk mechanically, as to excite the organ to excretion.

The irritation, produced by the child on the nipple, is the most powerful exciting cause of the determination of milk into the breasts; this irritation, or any other of the same kind, is sufficient to excite the secretion of milk, even under circumstances not provided for by Nature. It is thus that virgins have been enabled to suckle another mother's child; that young girls, under the age of puberty, have had so complete a secretion of milk, as to furnish a pretty considerable quantity of this fluid. There have been known men, in whom a long continued titillation of the breasts had determined so considerable an afflux of the humours, that there oozed from them, a whitish, milky, and saccharine fluid, not unlike the milk of a woman. The sucking of the new born child, is necessary to keep up the secretion of milk in the mammæ. It ceases to be formed in them, when the child is committed to the care of a different nurse; the mammæ, at first turgid, soon collapse, especially, if care have been taken to determine the fluids downwards, by exhibiting gentle laxatives.

The erection of the breasts, by titillation on the nipple, the spasmodic, and almost convulsive, action which follows this kind of excitement, may be carried so far as to produce an emission of the fluid to some distance. While its excretion lasts, women experience, in their breasts, an agreeable sensation; these parts are tense and swollen; they feel, as they express it, the milk rising;

several feel a sensation of extension reaching to the axilla, to the arms and chest. The whole mass of cellular substance surrounding the breasts and extending to the neighbouring parts, partakes in their activity.

The breasts, themselves, consist, in great measure, of cellular substance; an adipose and lymphatic layer, of a certain thickness, covers the gland, which is divided into several lobes, and encloses it within its substance. They receive a number of nerves, but very few blood vessels for their bulk.

Their structure appears almost wholly lymphatic; the vessels of this kind, after being distributed to the neighbouring glands, and especially to those of the axilla, penetrate into the breasts, in which their proportion, compared to that of the sanguineous vessels, is as eight to one. These lymphatic vessels, which enter in considerable numbers into the composition of the breasts, increase greatly in size, in nurses, and when injected in this condition, it has been ascertained, that several of them joined to form larger trunks, which going towards the nipple, contributed in forming what are called the lactiferous tubes. If the lymphatic vessels be immediately continuous with the excretory ducts of the breasts, there is reason to believe, that it is these vessels which convey the materials of the fluid which they separate, especially if it be considered, how small the number of minute arteries which are distributed into their tissue, and what a disproportion there is, between the caliber of these small vessels and the quantity of blood which the breasts supply. The opinion that the lymphatic vessels bring to the breasts the materials of the secretion of milk, is not in opposition to the laws of the circulation in the lymphatics; all who are acquainted with these laws, know that the course of the lymph, though, in general, from the circumference to the centre, is naturally liable to a number of aberrations or deviations, facilitated by the numberless anastomoses of these vessels. (XLV).

CCXXI. The granulated structure is not as apparent in the breasts, as in the other glandular organs, hence they bear a greater resemblance to the lymphatic, than to the conglomerate glands. The milk which they secrete, has always been considered as very like the chyle, which it resembles, in its white colour, its smell, and its saccharine taste. Like the chyle, it is the least animalized fluid, the sweetest, that on which the action of the organs produces the least effect, and that which preserves most the characteristic qualities of the food taken by the nurse.

It is well known, that instead of giving medicines to infants at the breast, we, most frequently, administer the medicine to the nurse; thus, the milk acquires purgative qualities and acts on the bowels of the child, when the nurse has been purged. The chyle is white and opaque, only in those animals which suckle their young; in the others, it is as transparent as lymph. (Cuvier).

In the last place, if the arteries carried to the breasts the materials of their secretion, these vessels ought to increase in size, when these organs become twice, or even three or four times larger than natural; in the same manner that, in open cancer, and in other similar affections, in which the determination of blood being increased, the caliber of the vessels is proportioned to them. Nothing, however, of the same kind occurs, whatever size the breasts may acquire from the presence of milk; their arteries preserve their almost capillary minuteness, as I had an opportunity of ascertaining, by injecting the mammæ of a woman twenty-nine years of age, who died in the second month of suckling, and whose breasts were remarkable by their size, and by the quantity of milk they were able to secrete.

Notwithstanding all these reasons, which have long made me adopt the opinion of the celebrated Haller, who considers the milk as immediately extracted from the chyle, I own that it must be considered as hypothetical, and resting solely on probability. The impossibility of demonstrating, anatomically, the branches going from the mesentery to the breasts, without communicating with the thoracic duct, gives still greater probability to the generally received opinion, which makes the milk, like all the other secreted fluids, with the exception of the bile, to be supplied by arterial blood.

The milk does not resemble chyle, in every respect, though it may be considered as extracted from the food*, changed in its way to the mammæ, by the glands through which it has passed, and especially by the action of the organs themselves. This action is so evident, that, as Bordeu observes: "There are women who seem to have no milk in their breasts, which are flaccid and empty; but as soon as the child excites them, they become distended, and the milk comes spontaneously." It is well known, and the same author has pointed has pointed it out, that women, cows, and the females of other animals, allow themselves more willingly to be sucked by a suckling that knows how to excite their sensibility, and to apply due irritation to the nipple; and that, on the contrary, they retain their milk, when the suckling does not excite the sensation in which they feel pleasure. It is thought, in some countries, that serpents know how to tickle the teats of cows, and that these animals enjoy this excitement and allow themselves to be sucked by these reptiles.

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* "Lac utilis alimenti est superfluum." Gal. De Usu part. Lib. VII, Cap. XXII.

CCXXII. *Of the physical properties of milk and of the chemical nature of this fluid.* The quantity of milk is, in general, proportioned to that of the aliments, to the degree of their nutritious qualities, to their moist and farinaceous nature. Though it equals, in weight, about one third of the quantity of food taken by the nurse, it may exceed that proportion, or may not come up to it. Its specific gravity, even when the milk is lightest, is greater than that of distilled water, and is always proportioned to its consistency. The latter quality is in an inferior degree, in woman, but is greater in the cow, the goat, the ass, and the ewe. Its fluidity is intermediate between that of aqueous and oily liquids, its colour, its smell and flavour have something very peculiar, and by which it is easily recognized; in the last place, it is not exactly alike, at different periods of the same milking. This is proved by the work of M. M. Deyeux and Parmentier on milk, a work abounding in valuable observations, and which may be considered as the complete history of this animal fluid. They observed, that the milk first drawn from the cow is serous, that its consistency gradually increases, and that the richest milk is that which is obtained towards the end of milking, as if the fluid contained in the udder were affected by the laws of gravitation.*

The milk, when exposed to the open air, in a vessel, becomes decomposed, like the blood, and separates into three parts; the serum, the curd or cheesy part, and the fatty part or cream. The latter, which is lighter than the others, is always on the surface, and its quantity depends, not only on the richness of the milk, but also on the extent of the surfaces by which it is in contact with the air; and this proves, as was first observed, by Fourcroy, that the oxygen of the atmosphere has some influence on its separation. The caseous part, which coagulates spontaneously, appears albuminous and abounds in oxygen. M. M. Parmentier and Deyeux consider it as the colouring matter of milk, and as giving to it its most characteristic properties. Lastly, the serum or whey, which alone constitutes the greatest part of this fluid, contains, besides a peculiar acid *(the lactic acid)* which is formed when this substance is allowed to remain for some time; a saccharine matter, which may be obtained by evaporation, and which, when crystallized in rhomboidal parallepipeds, constitutes the sugar of milk, whose purity depends on the degree of care with which the process has been carried on. This sugar of milk, contains, as Scheele first ascertained, while endeavouring, by means of the nitric acid, to convert it into the oxalic, a peculiar acid, in the form of a powder, difficult of solution, and to which he gave the name of saclactic acid. Milk may be considered as one of the most compound of the animal fluids, whose qualities are very variable and whose parts have but an imperfect affinity to each other. So that it is liable to spontaneous decomposition, and this takes place very easily. This kind of emulsion contains but a small quantity of azote, so that it retains its vegetable character. Hydrogen, carbon, and oxygen predominate in milk; in the last place, it contains several salts, amongst others, muriate of soda, muriate of potash, and phosphate of lime.

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* The author seems to forget that he is speaking of the cow, and that her udder hangs in a situation unfavourable to this hypothesis. T.

The presence of the two last of these substances, leads to the following considerations. Muriate of potash, as is observed by Rouelle, does not exist in the blood; the probability is, therefore, that it is not the blood which supplies the mammæ with the materials whence the milk is secreted, muriate of potash being found, in greater quantity, in milk, than muriate of soda. These salts of potash, on the contrary, are found, in considerable proportions, in the chyle, formed from vegetable substances; which would lead one to think, that milk is furnished by the absorbent system. The phosphate of lime which is found, in smaller quantity, in the urine of nurses, and which is wholly determined towards the mammæ, was absolutely necessary in a fluid which supplies nourishment to the new being, while the bones become indurated and all the parts acquire solidity.

If we now wish to inquire into the causes which render suction necessary, and which subject the new born child to this peculiar mode of nutrition, these causes will be found in the general weakness of its organs. The organs of digestion would have been incapable of extracting, from the aliments, their nutritive parts, these substances not having undergone the due degree of trituration, from the want of teeth and from the imperfect state of the other organs of mastication. It was of consequence, therefore, that the mother should perform this preliminary function, and that she would transmit the aliment ready digested*. It is not, however, to be imagined, that the milk passes, without undergoing any change, into the vessels of the child; the child digests the milk and obtains from it, in a short space of time, and without effort, a considerable quantity of nutritious particles, necessary to the rapidity of its growth.

The connexion between the mother and child is far from being broken, at the period of birth; the relations between them, though not so close, are not less indispensable. Before birth, the vital power was so limited in the child, that it was necessary it should receive a fluid already animalized, and in a state to yield to the function of assimilation and nutrition. When the child has breathed, when its strength is increased, it may be entrusted with a greater share of the process; it is then sufficient that the aliment should have undergone the first degree of elaboration, within the digestive canal. But it is not merely to assist in preparing its food, that the new born child requires the aid of the mother; its lungs, which are delicate and imperfectly evolved, do not supply a due quantity of oxygen to the blood which circulates through them; the animal heat would beunder what is required by the wants of life, if the mother did not make up for this deficiency, by transmitting some of her own warmth. She folds her infant gently to her bosom, warms it with her breath and by this kind of maternal incubation continues to cherish it with that calorific influence to which it was fully exposed, while forming a part of herself. Besides, she feels for it, keeps it from danger, foresees its wants, and understands its language; and this very interesting intercourse takes place, after the bonds of their physical communication are loosened, but it does not tear them asunder. The infant is, therefore, detached from the mother, only by degrees, since it is only in proportion as it grows older, that it acquires the means of living independent.

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* *Lac est cibus exactè confectus.* Galenus de usu partium.
Lib. VII, cap. XXII.

The secretion of of milk, in the breasts, may be prevented by irritation in the uterus. If the labour have been difficult, if the woman have suffered a certain degree of injury, the irritation, in the parts so affected, prevents the determination of the fluids towards the mammæ. Hence these organs collapse, during puerpeperal fever, not that the milk flows back into the humours and becomes the cause of the complaint, but that the inflammation of the uterus prevents the fluids from flowing in their natural direction.

During the first few days after delivery, the parietes of the uterus discharge a fluid, at first bloody, then of a reddish colour, and, in the last place, mucous, and whitish, termed the lochia.

CCXXIII. All the parts of the lungs are not distended with air, in the first inspirations of the child, after-birth. Some of the lobes, which are harder and more compact, take some time to admit this fluid, and even sometimes, altogether reject it. A child died, twenty one days after birth; the body was opened by Professor Boyer. On examining the lungs, he found that the posterior part of these organs was as hard and compact, as in the fœtal state. The anterior part alone was distended, contained air, could be felt to crepitate and floated in water. The heart was examined, to ascertain whether its structure was connected with this condition of the lungs, which depended on the want of power in the respiratory functions. The foramen ovale was found pervious, so that the blood could pass from the right into the left cavities of the heart, without flowing through the lungs. The child had been exceedingly languid, during the whole of its short life; its skin was, at times pale, at others livid. It was very difficult to keep it warm.

The child of Madame L**** died, nine days after birth, with the same appearances. I opened the chest, and found the upper part of both lungs indurated and compact; the foramen ovale was quite pervious. This aperture is often closed very imperfectly, so that there remains, at the upper part of it, an opening, varying in size, which would enable a small quantity of venous blood to pass from the right into the left auricle, if these cavities did not contract at the same moment, and if the fluid which they contain did not present eqnal resistance on both sizes. There are cases of persons in whom the foramen ovale remained pervious, and who, nevertheless, lived to a pretty advanced age. Their skin was purple and livid, all their moral and physical faculties feeble and torpid. It would be interesting to ascertain, by dissection, whether in good divers, who can remain a long while under water, without breathing, the foramen ovale is not imperfectly closed.

CHAPTER XI.

Containing the History of the Ages, the Temperaments and the Varieties of the Human Species; of Death, and Putrefaction.

CCXXIV. *Of infancy.* The epidermis of the new-born babe thickens, the redness of the skin grows paler, the wrinkles are effaced, the soft down, which covered the face, falls and disappears, the buttocks swell out and soon conceal the opening of the rectum. During the first months of life, it seems to need nothing but nourishment and sleep. In the mean while, the understanding is beginning to form, it looks fixedly at objects, and seeks to take cognizance of all the bodies that surround it. Confined, at first, to the uneasy sensations, which it expresses by almost continual tears, its existence becomes less painful, as it grows accustomed to the impressions of outward things upon its delicate organs. Towards the middle of the second month, it becomes capable of agreeable sensations. If it feels them before that time, at least it is only then that it begins to express them by laughing*.

CCXXV. *Dentition.* Towards the end of the seventh month†, the middle incisor teeth of the upper jaw, cut through the substance of the gums: a little while after, the corresponding incisors of the lower jaw shew themselves: next, the lateral incisors of the upper jaw, those of the lower, then the cuspidati, in the same order. At the age of between eighteen months and two years, the small molar teeth appear, but in reversed order, those of the lower preceding those of the upper jaw. When these molar teeth have come through, the first dentition is complete; the life of the child is more secure: it was before very uncertain, since the calculations of the probable duration of human life shew, that a third of the children born at any given time, die before the age of twenty three months. Convulsions and diarrheas are the most fatal accidents attending difficult dentition. To these twenty teeth are added two new grinders in each jaw, when the child has reached the end of his fourth year. These last will afterwards become the first large grinders. They differ from those that precede them in this, that they are to remain all life long, whilst the primitive or milk teeth are lost at seven years old, in the same order in which they appeared, and are replaced by new teeth, better formed, and larger, excepting the small grinders, and with longer and more perfect roots. Towards the ninth year, two new large grinders appear beyond the others. The child has then twenty eight teeth, and dentition is complete, though between eighteen and thirty, and sometimes much later, the dentes sapientiæ, two to each jaw, shew themselves at the extremities of the alveolar processes.

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* At Hercules risus præcox ille et celerrimus, ante quadragesimum diem nulli datur.

PLIN. Hist. Nat. Præf. ad lib. VIII.

† It would be very difficult to say, why a tertian fever often terminates of itself, when it has reached it seventh paroxysm, whilst a continued fever is judged of by critical evacuations, in seven, fourteen, or twenty one days; why delivery happens at the end of nine months; why the first teething begins at seven months old, the second, at seven years; why puberty shews itself, towards

The order observed in the successive cutting of the teeth is not so invariable, but it is frequently inverted. A child ten years old, now under my care, cut the four first small grinders before the canine teeth. Dentition is, in this respect, like all other acts of the living economy: instability is its principal character. An attentive examination soon shows how irregularly those phenomena proceed, whether physiological or pathological, which

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the fourteenth year, and menstruation is repeated at determinate periods. Nature appears to subject herself, in all her acts, to certain periods, which observation may ascertain, without any possibility of arriving at a knowledge of the causes of these phenomena so easy to establish. Because their manifestation is correlative to certain numerical terms, we are not to put faith, like Pythagoras, in the power of numbers, and believe that the number 3 and the numbers 7 and 9 enslave all nature to their supreme influence. We find traces of this ancient error in all sciences, in all religions, even in those of enlightened nations.

appear the most to be subjected to calculable and determinate periods*.

This double range of successive teeth existed in the jaws of the fœtus. Each alveolar process, at that age of life, contains two membranous follicles, lying one over the other. That which is to form the primitive tooth swells the first, a calcareous matter covers its surface and forms the body of the tooth, which invades also the follicle by which the osseous part is secreted, so that the growth of the little bone being completed, the membranous vesicle, in the parietes of which the dental vessels and nerves branch out, is found in the centre of its body, and adheres to the parietes of its internal cavity. It is difficult to say, why the growth of the dental germs is successive; why, in the seventh year, the primitive teeth are detached, and are replaced by others which have remained so long buried within the alveolar processes. Dentition is like all the other phenomena of the living economy; it is subject to endless varietes in its period and duration, &c. Thus, teeth of a third set have been known to be cut in very old people. There are instances, but they are very scarce, of children that have come into the world with two incisors in the upper jaw; there are often supernumerary teeth, &c.

CCXXVI, *Ossification.* The process which goes on in the osseous system, is not confined to the cutting and growth of the little bones which are attached to the two jaws. All other parts of the skeleton harden; osseous nuclei are formed in the centre of the cartilages, which hold the place of the short bones of the carpus and tarsus; the thickness of the cartilaginous substances, which separate the epiphyses of the bodies of the long bones, is diminished; the large bones grow, and acquire solidity, from the centre to the circumference. Those of the skull meet at their edges, their fibres cross and form the sutures; the cartilaginous spaces (*fontanels*) which were situated at the meeting of their edges and angles disappear. The urine contains exceedingly little phosphate of lime, that salt being entirely taken up in the solidification of the bones. About the middle of the second year, these have already acquired substance and solidity enough to support the weight of the body; the child can stand and walk. Before this time, it would be dangerous for him to try it: the pillars of support, yet too flexible, would yield under the burthen, and bend permanently in different directions. It is towards the head, that the vital motions tend in infancy: accordingly, this part is the principal seat of the affections peculiar to this age, affections in which it is often of use to procure local evacuations.

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* *See* Erreurs populaires, sec: edit: Chap. 4, *des Années climatériques, et des Jours critiques dans les maladies.*

The organs of the senses, open to all sorts of impressions, receive them with ease; but if, in early infancy, sensation is easy, it is very transient; no doubt from the want of consistence in the cerebral organ. As it grows older, the mobility of the child is lessened, without diminution of susceptibility; and it is during the years that precede the boisterous season of puberty, that he enjoys, in the highest degree, the faculty of recalling things that have affected him, that his memory is most distinct and extended; but soon overpowered by imagination, rouzed up by the powerful re-action of the sexual organs on the brain, it ceases to have the same exactness.

CCXXVII. *Of puberty.* Sex, climate, manner of life, have great influence on the earlier or later manifestation of the phenomena of puberty. Women reach it one or two years before men: the inhabitants of southern, long before those of northern countries. Thus, in the hottest climates of Africa, Asia, and America, girls arrive at puberty at 10, even at nine years old, but in France, not till twelve, fourteen, or fifteen: whilst in Sweden, Russia, and Denmark, the menstrual discharge, the most characteristic mark of puberty, is from two to three years later.

The male is known to be capable of generation, and that he begins to live the life of the species, by the emission of prolific semen, and the change of voice, which becomes fuller, more grave, and sonorous: the chin becomes covered with beard, the genitals with hair, and they attain rapidly their full size. The whole body grows; the general characters which distinguish the two sexes, and which are so obscure, before puberty, that they may often be mistaken, become very decided, and can no longer be confounded.

By all these signs of strength and virility, woman, urged by desires which may be termed wants, recognizes the being capable of gratifying them. The change of voice is the most certain of the indications of male puberty. It depends, as the following observations shew, on the developement of the vocal organs, which constantly accompanies that of the sexual parts.

CCXXVIII. A boy, aged 14, died in the year VII. at the Hospital of la Charité. On opening the larynx, I was surprized to see it so small; and especially the glottis, which was not above five lines in its antero-posterior diameter, and about a line and a half, in its transverse diameter, where its dimensions are greatest; an observation that must not be omitted, is, that he was very tall; but that the developement of the genital organs was as backward as of the vocal. I have repeated the same observation on subjects further from the age of puberty; I have extended my researches to those who had passed it, and I have obtained as a general result, that between the larynx and the glottis of a child of 3 or of 12, the difference of size is very inconsiderable, and cannot be estimated by the height of the figure:—

That, at the epoch of puberty, the organ of the voice enlarges rapidly, and that, in less than a year, the opening of the glottis increases, in the proportion of 5 to 10, that its extent is thus doubled both in length and breadth.

That these changes are less remarkable in women, whose glottis increases, in the proportion only of about 5 to 7; that in this respect, they still resemble children, as the tone of their voice would lead us to suppose.

These differences, in the size of the glottis, account for the danger which, in children, accompanies the croup. For, suppose an opening of a line and half in width, of which the edges are covered with a membrane of coagulable lymph, the opening will be entirely stopped: it would be only narrowed, if its width were double; a sufficient space would remain free for the passage of the air. This supposition, which I have employed to make myself understood, is only the expression of the truth, since anatomical inspection shews that the glottis, in adults, is double the size it is before puberty.

CCXXIX. *Menstruation.* The symptoms by which puberty is known, in women, are not less remarkable. The swelling of the genital organs straitens the opening of the canals that make part of them. The breasts become enlarged, and form, at the fore part of the thorax, marked projections. Further, there comes on a discharge of blood, which takes place, every month, from the vessels of the womb, and which is known by the name of the menstrual discharge, or menses. This periodical evacuation declares itself, in most women, by all the symptoms that indicate fulness of blood, as spontaneous lassitude, heat, and flushings in the face, and by others, which shew a direction of the humours towards the uterus, and a local plethora of that organ, as pains in the kidneys, and a certain itching of the parts. The first eruption puts an end to this state; which, in many, may be considered as real disease. A pure red blood, flows, in more or less abundance, for some days, the general heaviness goes off, and the woman feels herself relieved.

I shall not now speak of the many deviations incident to the menstrual discharge, and which must be considered as real diseases. Thus, the uterine discharge has been known to be supplied, by bleeding from the nose, hæmoptysis, melæna, sometimes by unusual evacuations of blood, from the eyes, ears, the fore finger, from ulcerated surfaces over different parts of the body.

It is easily conceived, that the different parts of the sanguineous system may supply each others place, and that the bloody secretion, in which menstruation consists, in failure of the internal surface of the uterus, may be carried on by another part, equally provided with capillary vessels: but that similar deviations may take place for the fluids secreted by the conglomerate glands, as urine, bile, saliva, is difficult to believe, notwithstanding the many testimonies and authorities that may be brought in support of this opinion.

The fluids are not in existence, before the work of secretion; the urine, retained in the bladder and in the ureters, the bile stopped in the gall bladder and the hepatic ducts, after it has been prepared by the peculiar action of the liver, may, it is true, from absorption, by the lymphatic vessels, be carried into the blood, and produce there a diseased urinary or bilious diathesis; occasion an irritation and derangement, after which, the humour of the cutaneous perspiration, and of the sweat, and the saliva itself will exhibit some of the qualities of the humour retained, and introduced, by the absorbents, into the circulation. The blood, contaminated by the admixture of a certain quantity of urine, may purify itself by various emunctories, by urinous vomitings and sweats; but that urine may, like the menstrual blood, come out at the eyes, the ears, or the navel, except in case of urinary umbilical fistula; that one whose urinary discharge, by the urethra, is not interrupted, may spontaneously vomit it, is what no man, who has any sound notions on physiology will believe; and yet it is related, with full details, in a late work, where these errors are found, in the midst of many interesting researches, on various points of physiological chemistry. I have seen myself the woman, whose urine has been so well analyzed by Dr. Nysten, when the clinical professor of medicine, at Paris, obliged her to submit to a severe but necessary examination, and I am astonished that well-informed men should so long have given credit to such gross impostures. The reader will, I hope, excuse this long digression, for the sake of its importance. Literary criticism is now carried on with such partiality, that no journalist, in praising justly what is praise-worthy, in the valuable work of Dr. Nysten, has pointed out the imposture of which he was the dupe.

At first irregular, the menstrual discharge assumes regularity, is repeated every month, and lasts from two days to a week, with evacuation of from three ounces to a pound of blood, every time. Women of sanguine temperament, robust and libidinous, are those whose menses last longest, and flow most copiously. The blood is arterial, red, and has not, in a healthy woman, any of the pernicious qualities which have been ascribed to it.

During the whole time of menstruation, women are weaker, more delicate, more susceptible of impressions; all their organs partake, more or less, in the affection of the uterus; and it is not difficult to an observer, of any practice, to discern the state, not merely by the state of the pulse, but by the change of the countenance and tone of the voice. Women then require very careful management. An improper blood letting, a purge, or any other remedy untimely administered, may suppress the discharge, and occasion the most serious affections. Climate evidently influences the duration and quantity of the discharge, since, in Africa, it flows almost continually, whilst in Lapland, it takes place, only two or three times a year.

I shall not dwell upon the different explanations that have been given of this phenomenon. Some have ascribed it to the oblique position of the uterus, without considering, that upon their principle, menstruation should take place, from the soles of the feet. Richard Mead believed that it depended on the influence of the moon over the female system; but why is it not then subjected to the lunar phases? Those who have found the cause of it, in plethora, general or local, have, if we admit their explanation, only changed the difficulty; for then, we must ask what are the causes of this plethora? But, if this opinion had any ground, nervous women, with a small quantity of blood in their system, ought not to menstruate; and yet they do so, plentifully. Must we ascribe menstruation to an acquired habit?

Is the problem resolved, by saying that all the secretory organs of women are too weak to evacuate the superfluity of humours, which would require for them a new emunctory? But is not this taking the effect for the cause? Does not this smaller quantity of fluids, proceeding from the blood, arise from the purification which the blood undergoes in the uterus? Let it be remarked, in the mean time, that this periodical discharge seems to exempt the sex from many inconveniences, from which ours suffers; such as gout, stone and gravel, so unfrequent with them, and so common with us. Nor can we avoid recognizing, in this discharge, a utility relative to conception: does it not seem to dispose the uterus to that function?* (CCIV).—Was it not requisite that this organ should be accustomed to receive a great quantity of blood, that pregnancy, which calls for this afflux, might not be injured, by bringing on a sudden change in the system, and the whole of the vital functions.

Menstruation is suspended during pregnancy; it is so during the first month of suckling; though this rule admits of many exceptions. Its cessation, in our climate, is from the fortieth to the fiftieth year; sometimes before, seldom later: though I have now before me the instance of a woman of seventy, who has not yet ceased to menstruate; a fact, which, after all, is nothing more surprising, than that of menstruation beginning at an early period of life. When menstruation ceases, the breasts collapse, plumpness goes off and the skin shrivles, and loses its softness, colour, and suppleness. This cessation is the cause of a great many diseases which break out, at this season of life, called the turn of life, and are fatal to many women: but then, it is observed, that when this period is past, their life is more secure, with more hope of prolonging it, than a man has, at the same age.

CCXXX. *Of manhood.* To youth succeeds manhood: which may be considered as beginning from the twenty-first to the twenty-fifth year. Then, all increase of the body, in height, is at an end. The processes are completely united to the body of the bones. But still, growth goes on in other dimensions. All the organs acquire remarkable hardness, solidity, and consistency.

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* The greater part of female quadrupeds have the parts of generation bathed in a reddish lymph, during the time of being in heat.

It is the same with the intellectual and moral faculties. To the empire of imagination, succeeds that of judgment. Man is capable of fulfilling all the duties of family and society. This period of life, to which we give the name of mature age, extends to the fiftieth or fifty-fifth year for men: it scarcely goes beyond the forty-fifth for women, with whom it begins also a little sooner. During this long interval, men enjoy the whole plenitude of their existence.

Although, in general, it is not difficult to distinguish, at first sight, a man of twenty-five, from one of fifty, the differences which mark them, depending on the quantity and colour of their hair, and on their muscular strength, are neither many nor very essential.

Let us avail ourselves of this age, during which the characters of the human species, merely sketched, in childhood and youth, take a more defined and lasting form, to trace the features of individuals and of races.

CCXXXI. *Of temperaments and idiosyncrasies.* We give the name of temperaments to certain physical and moral differences in men, which depend on the various proportions and relations among the parts that make up their organization, as well as upon different degrees, in the relative energy of certain organs. There is, besides, in each individual, a mode of existence which distinguishes his temperament from that of any other, to whom, however, he may bear great resemblance. We express by the term *idiosyncrasy*, these individual temperaments, the knowledge of which is of no small importance, in the practice of medicine.

The predominance of any particular system of organs, modifies the whole economy, impresses striking differences on the results of the organization, and has no less influence on the moral and intellectual, than on the physical faculties. This predominance establishes the temperament; it is the cause, and constitutes its essence.

If the heart and the vessels which carry the blood, through every part, are of predominant activity, the pulse will be sharp, frequent, regular, the complexion ruddy, the countenance animated, the shape good, the forms softened though distinct, the flesh of tolerable consistence, moderate plumpness, the hair fair and inclining to chesnut; the nervous susceptibility will be lively, and attended with rapid *successibility*, that is to say, that being easily affected by the impressions of outward objects, men of this temperament will pass rapidly from one idea to another; conception will be quick, memory prompt, the imagination lively; they will be addicted to the pleasures of the table and of love; will enjoy a health seldom interrupted by disease; and all their diseases, and these slight, modified by the temperament, will have their seat principally in the circulatory system (*inflammatory fever, or angeio-tenique; phlegmasiæ; acute hæmorrhage*) and will terminate, when moderate, by the mere force of nature, and require the use of the remedies, called antiphlogistic, among which, bleeding is the chief. The ancients applied the name of *sanguine* to this disposition of body; they considered it as produced by the combination of warmth and moisture, and had very correctly perceived that it existed in the young of both sexes, was heightened by the spring, the season which has been justly compared to youth, calling that age the spring time of life.

That the specific characters of the temperament I have just described, may shew themselves, in all their truth, it is requisite that the moderated developement of the lymphatic system, coincide with the energy of the sanguineous system, so that these two sets of vascular organs may be in true equipoise. The physical traits of this temperament are to be found in the statues of Antinous and the Apollo of Belvedere. Its moral physiognomy is drawn in the lives of Mark Antony and Alcibiades. In Bacchus are found both the forms and the character. But why seek amongst the illustrious men of antiquity, or among its Gods, the model of the temperament I have been describing, whilst it is so easy to find it among the moderns? No one, in my opinion, exhibits a more perfect type of it than the Marshal Duke of Richelieu, that man, so amiable, fortunate and brave in war, light and inconstant, to the end of his long and brilliant career*.

Inconstancy and levity are, in fact, the chief attribute of men of this temperament: excessive variety appears to be, to them, a necessity as much as an enjoyment; good, generous, feeling, quick, impassioned, delicate in love, but fickle, disgust, in them, follows close upon enjoyment: meditating desertion, in the midst of the most intoxicating caresses, they make their escape from beauty, at the very moment she thought to have bound them by indissoluble chains*. In vain he whom nature has endowed with a sanguine temperament, will think to renounce the pleasures of the senses, to take fixed and lasting likings, to attain, by profound meditation, to the most abstract truths; mastered by his physical dispositions, he will be for ever driven back to the pleasures from which he flies, to the inconstancy which is his lot; more fitted to the brilliant productions of wit, than the sublime conceptions of genius†. His blood, which a vast lung impregnates, plentifully, with atmospherical oxygen, flows freely in very dilatable canals, and this facility in the distribution and course of the humours is, at once, the cause and the image of the happy dispositions of his mind.

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* See his Memoirs, 6 vols. 8vo.

Voltaire has painted his character, with superior ability, in many verses addressed to him.

Rival du conquérant de l'Inde,
Tu bois, tu plais, tu combats, &c.

CCXXXII. If men of this temperament apply themselves, from circumstances, to labours which greatly exert the organs of motion, the muscles, plentifully supplied with nourishment, and disposed to acquire a developement proportioned to that of the sanguineous system, increase in bulk: the sanguineous temperament undergoes a great modification; and there results from it, the muscular or athletic temperament, conspicuous by all the outward signs of vigour and strength. The head is very small, the neck sunk, especially backward, the shoulders broad, the chest large, the haunches solid, the intervals of the muscles deeply marked.

The hands, the feet, the knees, all the articulations not covered by muscles, seem very small, the tendons are marked through the skin which covers them: the susceptibility is not great: feeling dull and difficult to rouze, the athlete surmounts all resistance, when he has once broken from his habitual tranquillity. The

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* The history of Henry IV. of Lewis XIV. of Regnard, and of Mirabeau proves that, to the extreme love of pleasure, sanguine men join, when circumstances require it, great elevation of thought and character; and can bring into action the highest talents, in every department.

† I have just met, in a gazette, with an assertion, at least singular. All the world knows, says the journalist, that Newton was sanguine, and this proves clearly, he adds, that temperaments have no influence on the intellectual powers. I would ask the journalist, where he has discovered that Newton was sanguine. The few details which biographers have preserved on the physical temperament of this illustrious philosopher, lead us to believe that his temperament was the melancholic, which is very frequently met with in England. I will not dare to pronounce absolutely, on subjects on which we can attain only a certain degree of probability; but, if Newton had been sanguine, he would not have carried his maidenhead with him to the grave, at the age of fourscore; as it is affirmed he did.

Farnese Hercules exhibits the model of the physical attributes of this particular constitution of body, and what fabulous antiquity relates of the exploits of this demi-god, gives us the idea of the moral dispositions that accompany it. In the history of his twelve labours, without calculation, without reflexion, and as by instinct, we see him courageous, because he is strong, seeking obstacles to conquer them, certain of overwhelming whatever resists him: but joining to such strength so little subtlety, that he is cheated by all the kings he serves, and all the women he loves. It would be difficult to find, in history, the example of a man who has combined, with the physical powers which this temperament implies, distinguished strength of the intellectual faculties. For excelling in the fine arts, and in the sciences, there is need of exquisite sensibility, a condition absolutely at variance with much developement of the muscular masses.

CCXXXIII. If sensibility, which is vivid and easily excited, can dwell long upon one object; if the pulse is strong, hard, and frequent, the sub-cutaneous veins veins prominent, the skin of a brown, inclining towards yellow, the hair black, moderate fulness of flesh, but firm, the muscles marked, the forms harshly expressed; the passions will be violent, the movements of the soul often abrupt and impetuous, the character firm and inflexible. Bold in the conception of a project, constant and indefatigable in its execution, it is among men of this temperament we find those who in different ages have governed the destinies of the world: full of courage, of boldness, and activity, all have signalized themselves by great virtues or great crimes, have been the terror or admiration of the Universe. Such were Alexander and Julius Cæsar, Brutus, Mahomet, Charles XII. the Czar Peter, Cromwell, Sixtus V. Cardinal Richelieu.

As love in the sanguine, ambition is in the bilious the governing passion. Observe a man, who, born of an obscure family, long vegetates in the lower ranks: great shocks agitate and overthrow empires: actor, at first secondary, of these great revolutions, which are to change its destiny, the ambitious hides, from all his designs, and by degrees, raises himself to the sovereign power, employing, to preserve it, the same address with which he possessed himself of it. This is, in two words, the history of Cromwell, and of all usurpers.*

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* Vie d'Olivier Cromwel, par Jeudy Dugour, 2 vol. 18mo.

To attain to results of such importance, the profoundest dissimulation, and the most obstinate constancy are equally necessary; these are, further, the most eminent qualities of the bilious. No one ever combined them in higher perfection, than that famous Pope, who slowly travelling on towards the pontificate, went, for twenty years, stooping, and talking, for ever, of his approaching death, and who, at once, proudly rearing himself, cries out "I am Pope*!" petrifying with astonishment and mortification, those whom his artifice had deceived into his party.

Such too was Cardinal Richelieu, who raised himself to a rank so near to the highest, and was able to maintain himself in it: feared by a King whose authority he established, hated by the great, whose power he destroyed, haughty and implacable towards his enemies, ambitious of every sort of glory, &c†.

The historians of the time inform us, that this celebrated minister shewed all the customary signs of the bilious temperament. Gourville tells us that he was, all his life, subject to a very troublesome hæmorrhoidal discharge‡.

This temperament is further characterized by the premature developement of the moral faculties. Scarcely past their youth, the men I have named projected and carried, into execution, enterprizes which would have been sufficient for their fame. An excessive developement of the liver, a remarkable superabundance of the biliary juices, most commonly accompanying this constitution of body, in which the vascular sanguineous system enjoys the greatest energy, to the prejudice of the cellular and lymphatic system, the ancients gave it the name of *bilious*. The diseases to which those distinguished by it are subject, involve, in fact, either as their principal characteristic, or as accessary circumstances, or as complication, the derangement of the action of the hepatic organs, joined to changes of composition in the bile. Among the remedies directed against these sort of diseases, evacuants, and especially emetics, are the best.

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* *Vie de Sixte Quint*, 2 vol. in 12.

† See his character drawn, with as much truth as eloquence, by Thomas, in the last edition of his *Essai sur les Eloges*.

‡ Memoires de Gourville.

If all the characteristics assigned to the bilious temperament are carried to the highest degree of intensity, and to this state is added great susceptibility, men are irrascible, impetuous, violent, on the lightest occasions. Such, Homer describes Achilles, and some others of his heroes.

CCXXXIV. When, to the bilious temperament, is added diseased obstruction of any one of the organs of the abdomen, or derangement of the functions of the nervous system, so that the vital functions are feebly or irregularly performed, the skin takes a deeper hue, the look becomes uneasy and gloomy, the bowels sluggish, all the excretions difficult: the pulse hard and habitually contracted. *(serré)*. The general uneasiness affects the mind; the imagination becomes gloomy, the disposition suspicious; the exceedingly multiplied varieties of this temperament, called by the ancients the *melancholic*, the diversity of accidents that may bring it on, such as hereditary disease, long grief, excessive study, the abuse of pleasures, &c. justify the opinion which Clerc has proposed, in his natural history of man, in a state of disease, where he considers the melancholic temperament less as a primitive and natural constitution, than as a diseased affection hereditary or acquired. The characters of Lewis XI. and Tiberius, leave nothing wanting for the moral determination of this temperament. Read, in the Memoirs of Philip de Commines, and in the Annals of Tacitus, the history of these two tyrants, fearful, perfidious, mistrustful, suspicious, seeking solitude by instinct, and polluting it, by all the acts of the most savage atrocity, and the most ungoverned debauch. Distrust and fearfulness, joined to all the disorders of imagination, compose the moral character of this temperament. The passage in which Tacitus paints the artful conduct of Tiberius, when he refuses the empire, offered him, after the death of Augustus, may be given as the most perfect model of it. *Versæ inde ad Tiberium preces, &c.* Corn. Tacit. *Annal.* lib. I.

As Professor Pinel very justly observes, in his treatise on insanity, the history of men celebrated in the sciences, letters, and arts, has shewn us the melancholic under a different light: endowed with exquisite feeling, and the finest perception; devoured with an ardent enthusiasm for the beautiful capable of realizing it in rich conceptions, living with men, in a state of reserve bordering upon distrust, analyzing, with care, all their actions, catching, in sentiment its most delicate shades, but ready in unfavourable interpretations, and seeing all things, through the dingy glass of melancholy.

It is extremely difficult to delineate this temperament in a general or abstract manner. Though the ground work of the picture remains always the same, its numerous circumstances give room for an infinite number of variations. It is better, therefore, to have recourse to the lives of illustrious men, who have exhibited it in all its force. Tasso, Pascal, J. J. Rousseau, Gilbert, Zimmerman, are remarkable among many others, and deserve, by their just celebrity, to fix our consideration. The first, born in the happy climate of Italy, proscribed and unhappy from his childhood, author, at twenty-two years old, of the finest epic Poem, the moderns can boast of, seized in the midst of the enjoyments of premature glory, with the most violent and most inauspicious love for the sister of the Duke of Ferrara, at whose court he lived: an extravagant passion, which was the pretext of the most cruel persecutions, and which followed him to his death; which took place towards the thirty-second year of his age, on the eve of a triumphal pomp which was prepared for him in the capitol.

The author of the Provincial Letters, and of the Thoughts, enjoying, like Tasso, a premature celebrity, almost on quitting childhood, was led to melancholy, not like him by the crosses of unhappy love, but by a violent and overpowering terror which left, in his imagination, the sight of a gulph for ever open at his side; an illusion which left him only at his death, eight years after the accident*.

No one, perhaps, has ever shewn the melancholic temperament, in a higher degree of energy, than the philosopher of Geneva. To be convinced of it, it is enough to read, with attention, certain passages of his immortal works, and especially the two last parts of his confessions, and the Reveries in the solitary walker: tormented with continual distrusts and fears, his fruitful imagination represents to him all men as enemies. If you believe him, the whole human race is in league to do him mischief, "*kings and nations have conspired together, against the son of a poor watchmaker*;" children, and invalids are brought in to execute these dreadful plots. But let us leave him to speak for himself, the most eloquent and most unfortunate man of the eighteenth century: "Here then I am, alone upon the earth, without brother, neighbour, friend, without society but myself; the most sociable and the most loving of men has been proscribed by them, with unanimous consent." This is the beginning of the first walk: further on he adds, "Could I believe that I should be held, without the smallest doubt, for a monster, a poisoner, an assassin, that I should become the horror of the human race, and the game of the rabble; that all the salutation of those that passed by me, would be to spit upon me; that a whole generation would amuse itself, with unanimous consent, in burying me alive?" It is idle to multiply quotations, in speaking of the works of a philosopher, who, in spite of his errors will, for ever, be the delight of all those who love to read and to think.

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* He died at 39. See his life by Condorcet.

The history of J. J. Rousseau, like that of all the melancholics who have distinguished themselves in literature, shews us genius struggling with misfortune; a strong soul lodged in a feeble body, at first gentle, affectionate, open and tender, soured by the sense of an unhappy condition, and of the injustice of men. Till the time when, impelled, by the desire of fame, Rousseau sprang forward in the career of letters, we see him endowed with a sanguine temperament, acting with all the qualities belonging to it; gentle, loving, generous, feeling, though inconstant: his fertile imagination shews him nothing but gay images, and, in this illusion of happiness, he lives on agreeable chimeras: but gradually undeceived by the hard lessons of experience, afflicted, in the depth of his heart, with his own wretchedness, and the wrongs of his fellow creatures, his bodily vigour wastes and decays, with it his moral nature changes, and he may be referred to as the most striking proof of the reciprocal influence of the moral on the physical, and the physical on the moral part of our being*. His history is a proof, beyond reply, that the melancholic temperament is less a peculiar constitution of the body than, a real disease, of which the

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* I have no doubt that the influence of the physical organization on the intellectual faculties is so decided, that we may regard as possible the solution of the following problem, analogous to that with which Condillac concludes his work on the origin of human knowledge.

The physical man being given, to determine the character and extent of his capacity, and to assign, consequently, not only the talents he possesses, but those he is capable of acquiring.

The profound meditation of the work of Galen *(quòd animi mores corporis temperamenta sequantur)*; the perusal of Plutarch's Lives of Illustrious Men, and of the other biographers and historians of ancient and modern times; of the degrees may infinitely vary, from a mere originality of character, to the most decided mania.

Gilbert arrives at Paris, with the germs of talents fitted for that great theatre. Poor and rebuffed by those on whom he had built his hopes, he mixes in the ranks of their detractors, and soon signalizes himself, among the most formidable, by a vigour worthy of a better cause. Persecuted, without respite, by want; the mortifying sight of the happiness which his enemies enjoyed, and to which he believed himself called, led him on to a state of perfect madness. He believes himself persecuted by the philosophers, who want to rob him of his papers: to save them from their imagined rapacity, he locks his manuscripts in a press, and swallows the key. It sticks at the entrance of the larynx, stops the passage of the air, and suffocates the patient, who dies, at the Hotel-Dieu, after three days of the most cruel sufferings.*

Zimmerman, early exhausted by study, already a physician of celebrity, at an early age, lives in solitude with an ardent imagination joined to the highest susceptibility: abandoned to himself, devoured with the thirst of glory, he gives himself up to labour in excess, publishes his Treatise on Experience, and the work

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Eulogies of Fontenelle, Thomas, D'Alembert, Condorcet, Vicq-d'Ayzr, &c. and the study of the medico-philosophical works of Haller, Cullen, Cabanis, Pinel, Hallé, who have modified and enriched the ancient doctrine of temperaments, will be of great avail in the search of this solution. "Philosophy," cries an eloquent writer, in the noble enthusiasm which seizes him at the sight of the riches accumulated by Fontana, in the Anatomical Museum at Florence, "Philosophy has been in the wrong, not to descend more deeply into physical man; there it is that the moral man lies concealed; the outward man is only the shell of the man within."

DUPATY, *33rd letter on Italy.*

* His life would have been preserved, if the cause of his illness had been understood, which he indicated himself by repeating for ever "the key chokes me." His state of madness made this pass for the words of a madman: but on opening the body, the key was found, of which the ward part was fixed at the entrance of the larynx: it would have been easy to draw it out, by putting a finger down the throat.

This unfortunate young man expressed, a few days before his death, the melancholy state of his soul, in stanzas most touchingly mournful: this is one, full of interest and simplicity;

Au banquet de la vie infortuné convive,
Je parus un jour, et je meurs;
Je meurs et sur ma tombe où lentement j'arrive
Nul ne viendra verser des pleurs.

on Solitude, so deeply imbued with the colouring of his soul. Forced from the solitude he loves, he carries, into the courts to which his reputation calls him, an inexhaustible store of bitterness and sadness, which political events supervening brought to greater excess: arrived at length gradually at the last term of hypochondria, he dies beset with pusillanimous fears, worthy of all eulogium and all regret.*

CCXXXV. If the proportion of the fluids to the solids is too great, this superabundance of the humours, which is constantly in favour of the lymphatic system, gives to the whole body considerable bulk, determined by the developement and repletion of the cellular tissue. The flesh is soft, the countenance pale, the hair fair, the pulse weak, slow, and soft, the forms rounded and without expression, all the vital actions more or less languid, the memory treacherous, the attention not continuous. Men of this temperament, to which the ancients gave the name of *pituitous*, and which we should call *lymphatic*, because it depends really on the excessive developement of this system, have, in general, an insurmountable inclination to sloth, averse alike to labours of the mind and body: accordingly, we are not to wonder, if we find none of them among Plutarch's Illustrious Men. Little fitted for business, they have never exercised great empire over their fellow creatures, they have never changed the face of the globe, by their negociations or their conquests. One of the friends of Cicero, Pomponius Atticus, whose history Cornelius Nepos has left us, conciliating to himself all the factions which tore the Roman republic to pieces, in the civil wars of Cæsar and Pompey, may be given as the model of it. Among the moderns, the easy Michel Montaigne, all whose passions were so moderate, who reasoned on every thing, even on feeling, was truly pituitous. But, in him, the predominance of the lymphatic system was not carried so far, but that he joined to it a good deal of nervous susceptibility. In the pituitous, from the excess of watery particles in the fluid which should carry every where heat and life, the circulation goes on slowly, the imagination is weak, the passions languid; and, from this moderation of the desires, spring, on many occasions, those *virtues of temperament*, which, to say it, by the bye, should not supply their possessors with matter of quite so much self-complacency.

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* See his Eulogium by Tissot; it is at the beginning of the last edition of the Treatise on Experience in Medicine. It there appears how deeply he was affected by the French revolution, of which he foresaw, with a sort of prophetic spirit, the disastrous consequences to his own country.

CCXXXVI. This property by which we are, more or less, sensible to impressions on our organs, weak in the pituitous, almost nothing in athletes, moderate in those of sanguine temperament, rather quick in the bilious, constitutes, by its excess, the nervous temperament;—seldom natural or primitive, but commonly acquired, and depending on a sedentary and too inactive life, on habitual indulgence in sensuality, on the morbid action of the brain promoted by reading works of imagination, &c. This temperament shews itself in the emaciation, in the smallness of the muscles, soft, and as it were, in an atrophy, in the vivacity of the sensations, in the suddenness and mutability of the determinations and judgments. Nervous women, whose wills are absolute but changeable, with excess of sensibility, frequently exhibit it with all these characteristics. Often, however, they have something of good looks, the extreme preponderance of the nervous system still allowing a moderate developement of the lymphatic. Spasmodic affections are not uncommon among them; and when it is observed that, on the other hand, the athletic constitution, directly opposite to the nervous temperament, predisposes to tetanus, may we not say, that the two extremes meet, or produce the same effects?

Anti-spasmodics are employed, with success, in the treatment of their diseases, which partake always, more or less, of the temperament. Stimulants, on the contrary, are very suitable to those of a pituitous or lymphatic temperament. The nervous temperament, like the melancholic, is not so much a natural constitution of the body, as the first stage of a disease. This temperament, like the nervous affections which are the result of it, has never shewn itself but among societies brought to that state of civilization, in which man is the farthest possible from nature. The Roman ladies became subject to nervous affections, only in consequence of those depraved manners which marked the decline of the Empire. These affections were extremely common in France, during the eighteenth century, and in the times preceding the fall of the monarchy. Of that epoch, are the works of Wytt, Raulin, Lorry, Pomme, &c. on nervous affections. Tronchin, a Genevese physician, acquired great wealth and reputation by the treatment of these diseases. His whole secret consisted in exercising to fatigue, women habitually inactive, keeping up their strength, at the same time, by simple, healthy, and plentiful food. The two most remarkable men of the eighteenth century, Voltaire and the great Frederick, may be given as instances of the nervous temperament; and the history of their brilliant and agitated life, shews, sufficiently, how much the circumstances in which they lived, contributed to develope their native dispositions.

I shall finish this article on temperaments by observing, that in truth, we bring with us into the world these particular dispositions of body; but that from education, manner of life, climate, acquired habits, they are altered, or altogether changed. Further, it is exceedingly rare to find individuals, who shew, in their purity, the characters assigned to the different temperaments: the descriptions given are drawn from an assemblage of individuals, much resembling one another. Their characters are pure abstractions, which it is difficult to realize, because all men are at once sanguine and bilious, sanguine and lymphatic, &c. In this instance, physiologists have imitated the artist, who united in the image of the goddess of beauty, a thousand perfections which he saw separate in the most beautiful women of Greece*.

It is an observation that the sanguine constitution is directly opposed to the melancholic, and never combines with it; that it is the same with the bilious and lymphatic: though it may happen that a man, sanguine in youth, shall become melancholic after a lapse of time; for, as I have said before, man never remains such as he came from the hands of Nature; fashioned by all that surrounds him, his physical qualities, at different periods of his life, are as much changed as his character.

Of all the causes that can modify the nature of man, and which will even change completely the nature of his native dispositions, there is none more powerful than the long-continued action of air, water, and residence, as the Father of Medicine has said. Climate, in fact, exerts upon the temperament the most marked influence. Thus, the bilious temperament is that of the greater part of the inhabitants of southern countries; the sanguine that of the nations of the north; the lymphatic constitution reigns, on the contrary, in cold and moist countries, like Holland. We have seen in what manner the athletic, melancholic, and nervous temperament grows out of our habits of life: let us now endeavour to appreciate the power of climate over the constitution of the greater part of mankind.

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* It is thus that, in the arts of imitation, the ideal grows up; now, from the exaggeration of features, now, from the union of qualities which Nature has produced separate.

It is known, that the influence of heat, in the production of bilious diseases is such, that after having been extremely prevalent, during the summer, they disappear, or at least become much less frequent, in the autumn. A notable increase of perspiration never takes place, without a proportional diminution in the quantity of the liquids with which the alimentary surfaces are moistened. Now, when the gastric juice is less abundant, the bile, being mixed with a smaller quantity of serosities, irritates more the intestinal surfaces; the digestive powers languish, and there is an approaching disposition to meningo-gastric fevers. The same influences, continued during the whole year in hot countries, must necessarily increase, with the activity of the biliary system, its power over the other parts of the economy, and thus establish a predominance of the bilious constitution, through both health and disease.

As for the sanguine temperament, so generally met with among northern nations, it is the necessary consequence of the continual and very energetic re-action of the powers of circulation, against the effects of external cold. It is only by the constant activity of the heart and vessels, that calorification can be effected with the necessary vigour. Now, the effects of this redoubled action are the same to the organs of circulation, as to the muscles under the influence of volition: in both, exertion increases the power of the organs exerted. The diseases of the nations of the North, analogous to their temperament, have, for the most part, their seat in the system of sanguineous vessels: their character is eminently inflammatory.

Lastly, the lymphatic state of nations, living under a moist climate, is nothing more surprising than the aqueous nature of plants, and small density of the wood, in trees growing under the influence of a foggy air. Animal bodies, like plants, absorb by their surfaces, and become gorged with humours, the excess of which always produces a remarkable slackening of activity in the organic motions.

The temperament of which the character is the predominance of one organ or system of organs, departs from that ideal state, where all the powers are reciprocally balanced, so as to exhibit in the living economy, a perfect equilibrium. This state, which has perhaps never been found, but in the imaginations of physiologists, and which was called by the ancients, the temperate temperament, *temperamentum temperatum*, being taken as the type of health, it follows that this temperament is already a step made towards disease. Yet the action of the predominant system is not in such excess as to destroy all equilibrium, and impede the action of life: but let the constitutional dispositions be much increased, the disease is begun, and this transition takes place, in the conversion of the lymphatic temperament into scrophula*. In the scrophulous constitution, there is, at once, activity of the absorbing mouths, great facility of absorption, inertness of the vessels and lymphatic glands, weakness of the absorbents, and consequently a thickening and stagnation of the liquids absorbed. The same thing is seen in the lymphatic temperament, characterized by the activity of the inhaling mouths, and the debility of the lymphatic system, as Professor Cabanis was aware†, when he refuted the opinion of those who ascribe the lymphatic temperament to the excess of activity in the absorbent system, though the only part of this system really quickened, is that which immediately performs absorption, whilst the rest is in a state of perfect atony.

CCXXXVII. *Varieties of the human species.* The power of producing, by copulation, like individuals, is considered, by naturalists, as the most certain test for fixing the species in red-and warm-blooded animals. This power of self-perpetuation, by a constant succession of similar beings, is found in all the races composing the human species, however different in colour, structure, and manner of life. Men, then, are but one species, and the difference that appears in them, according to the region of the globe they inhabit, can only constitute varieties or races. I admit, with M. Lacépède, the worthy continuator of Buffon, four principal races of the human species, which I shall call, like him, the European, Arab, the Mogul, the Negro, and the Hyperborean. We might add a fifth, of the American, were it not most probable, that the new Continent is peopled by inhabitants, who, coming from the old, either by land in the austral hemisphere, or along the immense Archipelago of the Pacific Ocean, have been altered by the influence of that climate, and the yet virgin soil, so that they are to be regarded less as a distinct race than a simple variety.

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* See *Nosographie Chirurgicale*, tome I. for the history of scrophulous ulcers, from which this paragraph is taken entire. The author, in that work, has aimed at introducing physiology into surgery, till then exclusively abandoned to explanations of the grossest mechanism.

† Of the relations of the physical and moral man, by G. Cabanis, Senator, Professor in the School of Medicine, in Paris, &c.

There is, in truth, this difference between varieties and races, that, in these last, there are implied, modifications more profound, more essential differences, changes not confined to the surface, but extending to the very structure of the body; whereas, to make a variety, nothing more is needed, than the superficial influence of climate on the integuments which it colours, and on the hairs which it makes longer or shorter, lank or curled, hard or soft. An Abyssinian, scorched by the heat of an almost tropical sky, is as black as the negro under the equator: yet they are by no means of one race, since the Abyssinian, a negro only in colour, resembles the European in the cast of his face, and the proportions of all his parts.

The characteristics of the European Arab race, which takes in the inhabitants, not of Europe only, but of Egypt also, Arabia, Syria, Barbary, and Ethiopia, are an oval, or almost oval face, in the vertical direction, a long nose, a prominent skull, long and commonly lank hair, a skin more or less white. These fundamental characteristics are no where more decided than in the north of Europe. The inhabitants of Sweden, Finland, and Poland, give the prototype of the race: their stature is tall, their skin of perfect whiteness, their hair long, lank, and of a light colour; the colour of the iris generally bluish. The Russians, the English, the Danes, the Germans, are already somewhat removed from this primordial type: the colour of their skin is of less pure white, their hair of a deeper hue. The French seem to stand midway betwixt the nations of the North and those of the South of Europe. Their skin is shaded with a deeper dye, their hair, less straight, and more of a chesnut and brown colour. The Spaniards, the Italians, the Greeks, the European Turks, and the Portugueze, are browner, their hair, in general, black. Lastly, the Arabs, the Moors, and the Abyssinians, have hair, in some measure, black and crisp, the skin tawny, and might serve for the step from the European Arab to the Negro race: which is, however, distinguished from them, by the flattening of the forehead, the smallness of the skull, the slope of the line measuring the height of the face, the thickness of the lips, the projection of the malar bones, and further, by a darker skin, thicker, greasy, and, as it were, oily, as well as by shorter, finer, curly, and woolly hair.

The Mogul race has the forehead flat, the skull jutting but little, the eyes looking rather obliquely outwards; the cheeks are prominent, and the oval of the face, instead of extending from the forehead to the chin, is drawn between the two malar bones. The Chinese, the Tartars, the inhabitants of the Peninsula, of the Ganges, and of the other countries of India, of Tonquin, Cochin-China, Japan, of the Kingdom of Siam, &c. compose this race, more numerous than all the others, and apparently more ancient also, which is spread over a far greater extent than the European Arab race, and yet more, than the Negro race, since it reaches from the fortieth to the sixtieth parallel of latitude, occupying an arc of the meridian of nearly 75°, whilst that which measures the countries of the European race is only of 50°, and the Negro race lying under the equator, between the tropics of Cancer and of Capricorn, is bounded within the limits of an arc of from 30 to 35°.*

The Hyperborean race, situated in the North of the two continents, in the neighbourhood of the polar circles, composed of the Laplanders, the Ostiaks, the Samoiedes, and the Greenlanders, is characterized by a flat flace, a squat body, and a very short stature. This degraded portion of the human species derives, evidently, from the climate, its distinctive characteristics. Striving, for ever, with the inclemency of a severe climate, the destructive action of an icy temperature, Nature, fettered in her motions, shrunk in her dimensions, can produce only beings whose physical imperfections explain their almost barbarous condition.

The small progress of the Negroes in the study of the sciences, and in civilization, their decided taste, and singular aptitude for all the arts which require more taste and dexterity, than understanding and reflexion, as dancing, music, fencing, &c. the figure of the head, which is midway between that of the European and the ourang-outang†, the existence of the intermaxillary bones, at an age, when, with us, the traces of their separation are completely effaced; the high situation and small developement of the calf of the leg, have been arguments more specious than solid to those who have endeavoured to abase this portion of the human species, in order to justify an iniquitous traffic, and a cruel tyranny; reproaches of civilized men, which they must wipe off by other means than a presumptuous assertion of their own dignity, or a proud insult on the native character of those, whom they themselves have cast into degradation.

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* Lacépède, Géographie Zoologique.

† The black colour of the skin, in Negroes, seems owing, as I have already said, to the scorching of the gelatine, which is the base of the rete mucosum of Malpighi. This colour, acquired in a long succession of ages, perpetuated and transmitted by generation, is become one of the characteristic features of the

Without admitting this belief, which owes its origin to a thirst of riches, we cannot help acknowledging that the differences of organization,draw,after them,a striking inequality in the developement of the moral and intellectual faculties. This truth would appear, in its full light, if, after summarily indicating, as I have just done, the physical characteristics of the races of men, I could unfold their moral differences, as real, and not less marked: opposing the activity, the versatility, the restlessness of the European, to the indolence, the phlegm, the patience of the Asiatic, examining what is the power, on the character of nations, of fertility of soil, serenity of sky, mildness of climate; shewing by what catenation of physical and moral causes, the empire of custom is so powerful over the people of the East, that we find in India and China the same laws, manners, and religion, which prevailed there long before our era: inquiring by what singularity, well worthy the meditation of philosophers and politicians, these laws, this worship, and these manners have undergone no change, amidst the revolutions which have so often taken place among those nations many times conquered by the warlike Tartars; showing, how, by the irresistible ascendancy of wisdom and knowledge, ignorant and ferocious conquerors have adopted the usages of the nations they had subjugated: and proving that the stationary condition of the sciences and arts among those who, so long before ourselves were in possession of the advantages of civilized society,

Negro race. M. Volney, in a work which should be a model to all travellers, grounds on the face of the blacks, a conjecture as ingenious as it is probable. He observes, that it exhibits, precisely, that state of contraction,which our face takes, when it is struck by light, and a strong reverberation of heat: then, says this philosophical traveller, the brow contracts, the cheek-bones rise,the eye-lid contract, and the lips project. Must not this contraction of the moveable part have influenced, in course of time, the hard parts, and even moulded the structure of the bones? *Voyage en Syrie et en Egypte*, Tom.1. pag. 70. 3ieme Edition.

is derived not so much from the imperfection of their organization, as from the degrading yoke of a religion loaded with absurd practices, and which makes knowledge the exclusive birthright of a privileged cast*. But such an undertaking, besides exceeding the limits I have prescribed myself, does not belong directly to my subject.

The *Albinoes* of Africa, the *Cagots* of the Pyrenees, and the *Cretins* of the Valais, cannot be given as varieties of the human species. They are infirm, feeble, degraded beings, incapable of reproducing an existence, which has fallen to them, in the midst of a healthy, vigorous, and robust population.

We are not to believe what some travellers have written on the existence of tribes of Giants, that have appeared on the Magellanic Coasts. The Patagonians, concerning whose stature there is so little agreement in relations, are men very well formed, and whose stature does not exceed ours, more than nine or ten inches. The Laplanders, whose stature is the smallest, are as much below, as the Patagonians are above; it does not exceed from four foot to four and a half. In the midst of ourselves, individuals reach from time to time, a stature sufficient to entitle them to the name of giants, whilst others, shrunk in all their proportions, are a renewal of the pygmies. Such was Bébé, the dwarf of Stanislaus King of Poland; Goliah, spoken of in the Book of Kings, Ch. xvii. v. 4. the King Og, Deut. Ch. iii. v. 2. and many others, whose stature varies from six to ten feet high.

CCXXXVIII. *Of old age and decrepitude.* The human body which, from the twentieth year of life, ceases to grow in height, increases in every other dimension, during the twenty succeeding years. After this period, far from growing, it begins to decay, and loses daily a part of its strength. The decay proceeds at the same rate as the growth, and is not more rapid, since man requires from thirty to forty years in reaching to his full growth, and takes about the same time in his progress to the grave, provided no accident hurries him to an untimely end.* The whole bulk of the body diminishes, the cellular tissue becomes collapsed, and the skin wrinkled, especially that of the forehead and face. The hairs of the head and over the rest of the body turn gray, then white; the organic action becomes languid; the fluids become more disposed to putrefaction (Hunter); hence, at this period of life, all diseases of debility are more frequent, and attended with greater danger.

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* See, concerning the Religion of the Bramins, and the Indian customs, Raynal's Philosophical History. We must assign further as a main cause of the want of progress of the Indians and Chinese, in the arts and sciences, sprung from civilization, the imperfection of their alphabet, which, being composed of a multitude of characters, which do not, like ours, represent sounds, but ideas. It is no part of my object to shew, how much signs so defective must confine the sphere and fetter the combinations of the mind.

Decay succeeds old age. The sensibility of the organs is blunted; the physical and intellectual faculties undergo a gradual decay; man ceases to be impressed, in the same manner, by surrounding bodies. His judgments are incorrect, because self-love preventing him from being aware of the changes which he has undergone, he is more disposed to ascribe to an universal degeneracy, the difference which exists between the sensations which he now experiences, and those which he experienced in his youth (laudator temporis acti). The digestion is bad, the pulse weak and slow; absorption difficult, from the almost complete obliteration of the lymphatics and the induration of the conglobate glands; the languid secretion and imperfect nutrition. The old man is slow in all his actions, and stiff in all his motions; his hair falls off, his teeth drop from their sockets; the cartilages ossify; the bones grow irregularly and become anchylosed, their internal cavity enlarges; all the organs become indurated, and the fibres dried and shrivelled. The bones become heavier, from the gradual accumulation of phosphate of lime, and if those of the skull, as is justly observed by Sœmmering, on the contrary, become lighter, it is that they are, in a manner worn out, by the continued motions of the skull, on their internal surface.

The ossification of some of the cartilages, for example, of those of the ribs and vertebræ, is productive of remarkable effects. The ribs becoming soldered, in a manner, to the sternum, perform very imperfectly, their natural motion of elevation and twisting, (LXXI) which produces the enlargement of the chest. This cavity dilating less fully, the pulmonary combinations, which are the abundant sources of animal heat, take place, in a less effectual manner, which, joined to a want of tone and energy in the lungs, and in all the organs, lowers the temperature of old people, as was observed by the father of Physic,* a circumstance, however, which has been denied by Dehaen.

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* The duration of life may be estimated by that of the growth. A dog ceases to grow, at the end of two or three years, and lives only ten or twelve; Man, whose growth requires a space of from twenty to thirty years, attains to the age of ninety or a hundred. Fishes live several centuries, their developement requiring a considerable number of years.

Those fibro-cartiliginous laminæ, with oblique fibres crossing each other, which unite, so firmly, the bodies of the vertebræ, become indurated, dried and shrivelled, sink under the weight of the body, and do not recover their former thickness, so that the stature is really reduced; besides, the weakened condition of the muscles, which raise the trunk, makes the weight of the viscera bend forward the vertebral column, whose different parts may remain fixed in this attitude, so that the whole column, consisting of twenty four vertebræ, may come to consist of only seven or eight distinct bones. It should not be imagined, however, that all the soft parts become more compact, for several, as Haller observes, the muscles, for instance, become softer,† and seem, in losing a part of their vital properties, to draw towards a speedy dissolution; not that death is entirely owing to the accumulation of phosphate of lime, which enters into the composition of all the organs, converts into ossific matter, the whole osseous system, and interrupts the action of the animal machine. If this ossific matter invade every part of the animal system, it is because the digestive powers, gradually weakened, cease to affect, in a suitable manner, the alimentary substances. The exuberance of calcareous salts is, therefore, not so much the cause as the effect of the successive destruction of the vital powers.

The slowness, the rigidity, and the difficulty of moving do not depend so much, as is thought, on the induration of the ligaments and other fibrous organs; these ligaments become softened and relaxed, to a considerable degree, so that luxation is more easily performed, after death, in old people. In them, likewise, organs, which, in youth, have a degree of consistency, become flaccid and soft; this is the case with the heart, which becomes collapsed in old people, its cavities remaining entire, while, in young persons and in adults, their parietes are not in close contact.

The brain becomes harder and firmer, less soluble in alkalies; its albumen appears less completely oxydized than in younger subjects: impressions are less easily made, and the motions necessary to the operations of the understanding are performed with difficulty. Hence, in decrepitude, man returns, as far as relates to his intellectual faculties, to a state of second childhood, limited to certain recollections which are, at first, confused and, in the end, completely lost, incapable of judgment or will, or of new impressions; sleep resumes its influence; reduced to a mere vegetative existence, he sleeps the greatest part of the day, and wakens only to satisfy his physical wants, and to take food, which he digests very imperfectly. For, in the first place, the want of teeth prevents his being able to divide sufficiently the different substances, and, in the next place, the supply of saliva, of gastric and intestinal juices is almost interrupted; the bile and other fluids are less active, and the intestinal tube is without energy. Universal rigidity will be admitted as one of the principal causes of death, if it be considered that women, in whom the organs are naturally softer, are longer in reaching that state, are more retentive of life than men, and, generally, live to a greater age.

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* Senibus autem modicus est calor * * * frigidum est enim ipsorum corpus. Hippocr. Aph. 14, Sect. 2.

† Non ergò in sola rigiditate causam senii mortis oportet ponere; nam ex defectu irritabilitatis, plurimi in senibus musculi languent, mollesque pendent. Elementa physiol. tom. VIII 4°. lib. 30.

The body, therefore, dies slowly and by degrees, says the eloquent M. De Buffon; life gradually becomes extinguished, and death is but the last term of this series of degrees, *the last shade (nuance) of life.*

CCXXXIX. *Of death.* Long, in fact, before the close of life, man loses the power of reproduction; and, in the course of the agony which serves as a passage between life and death, the organs of sense first become insensible to all sorts of impressions; the eyes grow dim, the cornea fades, the eye-lids close, the voice becomes extinct, the limbs and the trunk motionless; yet the circulation and respiration continue to be carried on, but at last cease, first in the vessels furthest from the heart; and then, gradually, in the vessels nearest that organ. Respiration, gradually slackened, being entirely suspended after a strong expiration*, the lungs no longer transmit the blood which the veins bring, from every quarter, to the heart. This fluid stagnates in the right cavities of the heart, and these die last, (*ultimum moriens*) and distended by the blood which collects within them, they attain a capacity exceeding greatly that of the left cavities, which are, to a certain degree, emptied.

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* Does this last and powerful expiration, often attended by sighing, depend on the spasmodic contraction of the muscles of expiration; or rather does it not depend on the re-action of the elastic parts which form the chest, a re-action which suddenly ceases to be counter-balanced by the vital properties.

Such is the course of natural death; the brain ceases to receive from the weakened heart, a sufficient quantity of blood to keep up sensibility; there remains still some degree of contractility in the respiratory muscles; it is soon exhausted, however, and the circulatory motion of the blood ceases with the life of all the organs, of which this fluid is one of the principal movers.

As to accidental death, it is always determined by the cessation of the action of the heart and brain; for, the death of the lungs occasions that of the whole body, only by preventing the action of the heart, by interrupting its influence on the encephalic organ. In natural death, therefore, life becomes extinguished, from the circumference to the centre; in accidental death, on the contrary, the centre is affected before the extremities.

Bichat, in his work entitled, *Recherches sur la vie et la mort*, has given a very complete account of the manner in which the organs of the animal economy cease to act in articulo mortis; but like all the authors who went before him, he has limited his inquiries to certain functions. No one has attempted to extend them to the phenomena of the action of the brain, nor has any one traced the order in which the various faculties of thought and of sensation vanish. I shall endeavour faithfully to mention the results of several hundred observations of my own on this subject.

The close of life is marked by phenomena similar to those with which it began. The circulation first manifested itself, and ceases last. The right auricle is the part first seen to pulsate in the embryo, and, in death, is the last to retain its motion. The phenomena of nutrition to which the fœtal existence is, almost entirely, limited, continue, even when the organs destined to establish a relation with the beings that surround us, have long been sunk into a slumber from which they are never to be róuzed.

The following is the order in which the intellectual faculties cease and are decomposed*. Reason, the exclusive attribute of man, first forsakes him. He begins by losing the faculty of associating judgments, and then of comparing, of bringing together, and of connecting a number of ideas, so as to judge of their relations. The patient is then said to have lost his consciousness, or to be delirious. This delirium has, generally, for its subject, the ideas that are most familar to the patient, and his prevailing passion is easily recognized. The miser talks, in the most indiscreet manner, of his hidden treasures, the unbeliever dies haunted by religious apprehensions. Sweet recollections of a distant native land, then it is that ye return with your all powerful energy and delight!!

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* I need not inform the reader, that I am not here speaking of the immortal soul, of that divine emanation which outlives matter, and which, freed from our perishable part, returns to the Almighty. I am speaking merely of the intellectual faculties common to man, and to those animals which, like him, are provided with a brain.

After reasoning and judgment, the faculty of associating ideas is next completely destroyed. The same occurs in fainting, as I once experienced in myself; I was conversing with one of my friends, when I experienced an insuperable difficulty in associating two ideas, from the comparison of which, I wished to form a judgment. Yet syncope was not complete, I still preserved memory and the faculty of feeling. I could distinctly hear those about me say, he is fainting, and exert themselves to relieve me from this condition, which was not without enjoyment.

The memory then fails.—The patient who, during the early part of his delirium, recognized the persons about him, no longer knows his nearest and most intimate friends.

At last, he ceases to feel, but his senses vanish in succession and in a determinate order; the taste and smell cease to give any sign of existence; the eyes become obscured by a dark and gloomy cloud; the ear is yet sensible to sound and noise, and, no doubt, it was, on this account, that the ancients, to ascertain that death had really taken place, were in the habit of calling loudly to the deceased.

A dying man, though no longer capable of smelling, tasting, hearing, and seeing, still retains the sense of touch; he tosses about in his bed, moves his arms in various directions, and is perpetually changing his posture; he performs, as was already said, motions similar to those of the fœtus within the mother's womb.

CCXL. *Of the period of death.* This period is nearly the same with all men, whether they live near the poles, or under the equator, whether they live exclusively on animal or vegetable substances, whether they lead an active life, or consume their existence in disgraceful sloth: few live beyond a hundred years. There are, however, cases of men who have lived far beyond that period as, for example, those men mentioned in the philosophical transactions, one of whom lived to a hundred and sixty five.

Few men, however, attain a hundred years, and death, even when natural, overtakes us from the age of seventy five to a hundred.

Difference of climate though producing no difference in the duration of life, has, however, a remarkable influence on rapidity of growth. Puberty, manhood, and old age, come on much sooner in warm climates, than in northern countries, but this premature developement which shortens the duration of the periods of life, augments, in the same proportion, that of old age

It is, however, difficult to say, at what precise period, old age begins. Is it towards the fortieth year, when the body begins to decrease and to decay? Can the change of the colour of the hair be considered as the certain sign of old age? We daily see young men with gray hair. May we determine its accession, by the cessation of the functions of generation and the incapacity of reproduction? Fecundity, whose term is so easily determined in woman, by the cessation of the menses is, in man, very equivocal; the emission of seminal fluid is an uncertain sign, from the difficulty of distinguishing the mucus of the vesiculæ seminales and of the prostrate, from the truly prolific semen. Erection is likewise a sign not to be relied upon; this state may be occasioned by sympathetic irritation, by the compression of the bladder, distended with urine, on the vesiculæ seminales. It is more difficult than is imagined, to determine, from observation, the period at which, in the human species, the male is entirely deprived of the power of generation, and it may be said that, in establishing the period of from forty-five to fifty-five, as the beginning of old age in our climate, there will be found men arrived at that state, before having reached that age; as, on the other hand, others will be found after the age of fifty-five, with all the characters of manhood. The climacterical period of sixty-three is the decided and confirmed period of old age. Whatever regimen may have been followed, man, at that age, is truly old and cannot but be aware of it.

CCXLI. *Of the probabilities of human life.* Man dies at all ages; and if the duration of his life surpass that of the lower animals, the great number of diseases to which he is liable, renders it much more uncertain, and is the cause why a much smaller number arrive at the natural term of existence. It has been attempted to discover what are the probabilities of life, that is, to ascertain, from observation, how long a man may expect to live, who has already reached a determinate age. From late accurate observations of the age at which a number of persons have died, and from a comparison of the deaths with the births, it has been ascertained, that about one fourth of the children that are born, die within the first eleven months of life; one third before twenty-three months; and one half before they reach the eighth year. Two thirds of mankind die before the thirty-ninth year, and three fourths before the fifty-first; so that as Buffon observes: of nine children that are born, only one arrives at the age of seventy-three; of thirty, only one lives to the age of eighty; while out of two hundred and ninety one, only one lives to the age of ninety; and in the last place, out of eleven thousand, nine hundred, and ninety-six, only one drags on a languid existence to the age of a hundred years.

The mean term of life is, according to the same author, eight years, in a new-born child. As the child grows older, his existence becomes more secure, and and after the first year, he may reasonably be expected to live to the age of thirty-three. Life becomes gradually firmer up to the age of seven, when the child, after going through the dangers of dentition, will probably live forty-two years and three months. After this period, the sum of probabilities which had gradually increased, undergoes a progressive decrease; so that a child of fourteen cannot expect to live beyond thirty-seven years and five months; a man of thirty, twenty-eight years more; and, in the last place, a man of eighty-four, one year only. From the eighty-fifth to the ninetieth year, probabilities remain stationary, but after this period, existence is most precarious and is painfully carried on to the end. Such is the result of observation, and of calculations on the different degrees of probability of human life, by Halley, Graunt, Kersboom, Wargentin, Simson, Deparcieux, Dupré de St. Maur, Buffon, d'Alembert, Barthez, and M. Mourgues, who has just published his observations, collected at Montpellier, in the course of a great number of years, and with the most scrupulous accuracy.

I should enter more fully into this subject, but that it belongs more to the department of political economy than to that of physiology.

The calculations on the probabilities of human life, present results applicable to the generality of cases, since the mean duration of existence is nearly the same with all men, in all countries and climates*. The shepherd of the Pyrenees, who lives happy in the innocence of a pastoral life, breathing the pure air of his mountains, is, in this respect, subject to the same laws as the inhabitant of populous cities, exposed to the inconveniences attending numerous collections of men; inconveniences, which viewed in a philosophical point of view, or which greatly over-rated, have so often furnished a text to the meditations of philosophy, and to the idle declamations of oratory.

Does life experience a progressive diminution, in proportion to the duration of the world, and to say nothing of the time preceding the flood, when, according to the Book of Genesis, men lived several hundred years, did the men of former times live longer than those of our own? This is very improbable; among the Egyptians, the Hebrews, the Greeks, and Romans, there were very few instances of persons living to the age of a hundred years, and instances of longevity are perhaps more frequent among the moderns.

The art of providing for the wants of life, making daily progress, it is very probable, that far from being shortened, the term of human life may be lengthened a certain number of years beyond its ordinary duration. This idea is, it is true, contrary to the commonly received opinion of the progressive depravity of mankind in all ages; but the golden age never existed, but in the imagination of poets, and the daily complaints of morose old age have their origin in motives easily understood by the physiologist. He whose sentiment is blunted by a long course of years, is affected, in a very different manner, by surrounding objects. As to the old man, flowers have lost their scent and beauty, fruits no longer retain their flavour. The whole of nature seems dull and colourless. But the cause of all these changes is within himself, every thing else remains as it was. Always equally fruitful, Nature exposes every thing to the action of her inexhaustible crucible; maintains every thing in a state of everlasting youth, and preserves a freshness ever renewed. Individuals die, species are renovated; life every where arises in the midst of death. The materials of organized bodies enter into new combinations and serve in forming new beings, when life ceasing to animate those to which they belonged, putrefaction seizes upon them, and effects their destruction.

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* The researches of Sir John Sinclair do not disprove this statement, though this author adheres faithfully to the practice generally adopted by his countrymen, of speaking most favourably of England and Scotland. The statistical tables published in different parts of Europe, show that the number of people who reach the age of a hundred is equally great there.

CCXLII. *Of putrefaction.* Here the history of life ought to terminate; if, however, it be considered that the changes which bodies experience, after death, throw a considerable light on its means, its ends, and its nature, there will be an obvious necessity for shortly inquiring into the different phenomena which accompany the decomposition of animal substances. And this investigation appears to me to belong to the department of physiology, until the aspect of the body ceases to recall the idea of its former state, and until the last lineaments of organization are completely effaced. As soon as life forsakes our organs, they become subject to the laws of physics, operating on substances that are not organized. An inward motion takes place within their substance, and their molecules have the greater tendency to become separated from one another, as their composition is more advanced. Chemistry informs us that the tendency to decomposition of bodies is, in direct ratio to the number of their elements, and that a dead animal body is capable of remaining unchanged, in proportion as its composition is more simple and its constituent principles less numerous and less volatile.

Before putrefaction can come on in the human body, it must be entirely deprived of life, for, the vital powers are most powerfully antiseptic, and one might say that life is a continual struggle against the laws of physics and chemistry. This vital resistance, alluded to by the ancients when they said, that the laws of the microcosm were in perpetual opposition to those of the universal world, and that these, in the end, prevailed; this power which is in a state of perpetual re-action, manifests itself in life: the latter, considering only the results, might, therefore, be defined as follows: *the resistance opposed by organic bodies to the causes incessantly tending to their destruction.* By attending to all these phenomena, it will be seen that all of them tend to one end, the preservation of the body, and that they obtain it, only by keeping up a perpetual struggle with the laws which govern inorganic substances.

It might appear singular, that death should furnish a just idea of life, did we not know that it is by comparing, that we are enabled to distinguish, to judge, and to arrive at knowledge.

Putrefaction takes place and is completed, only in substances deprived of life. A mortified limb loses its vitality, before putrefaction comes on, and if nature preserve sufficient energy to resist this destructive process, she draws, by a line of inflammation, the separation, between the dead and the living part. Life and putrefaction are, therefore, two absolutely contradictory ideas; and when, in some diseases, there is observed a tendency in the solids and fluids to spontaneous decomposition, this tendency to putrefaction should not be mistaken for putrefaction itself.

Several conditions are required to enable putrefaction to affect the human body, after death. In the first place, a mild temperature, that is, above ten degrees of Réaumurs thermometer: in the next place, a certain degree of moisture and, lastly, the presence of air. This last condition, however, is not so necessary as the two former, since substances undergo putrefaction, in a vacuum, though more slowly. The air consequently promotes decomposition, only by carrying off the elements which rise in vapours. On the other hand, an icy cold, or a degree of heat approaching to boiling, prevent it; the former, by condensing the parts; the second, by depriving them of moisture, the complete absence of which, accounts for the preservation of the Egyptian mummies.

The phenomena of putrefaction, resulting from a series of peculiar attractions, are modified in various ways, according to the nature of the animal substances which are subjected to it, to the media in which it takes place, to the different degrees of moisture and temperature, and even according to its different periods. Notwithsanding these innumerable varieties, one may say, that all exhale a certain cadaverous smell, are softened, increase in bulk, acquire heat, change colour, assume a greenish, then a livid and dark brown colour; there are, at the same time, disengaged a great number of gazeous substances, of which ammonia is the most remarkable, either from its quantity, or from being given out by animal substances, from the moment when decomposition begins, to the period of the most complete dissolution. This gas produces the pungent and putrid smell which exhales from dead bodies.

Towards the termination of putrefaction, there is disengaged carbonic acid gas, which combining with ammonia, forms a fixed and crystallizable salt. Besides these products, there are given out sulphureted and phosphureted hydrogen, or combined with azote, carbonic acid, and all the substances that may be produced by their respective combinations. In the last place, animal substances, when reduced to a residue containing oils and salts of different kinds, form a mould, from which plants draw the principles of a luxuriant and vigorous vegetation. The bones, those least alterable parts of the organized machine, in time, become dried by the slow combustion of their fibrous part, and by the evaporation of their medullary juices. At last, reduced to an earthy skeleton, they crumble into dust, and this dust is dissipated, on opening the tombs in which they were laid.

Thus, in course of time, is effaced all that could recall the idea of our physical existence.

Putrefaction, considered in a philosophical point of view, is but a means employed by nature, to restore our organs, deprived of life, to a more simple composition, in order that their elements may be applied to new creations. *(circulus æterni motûs.**) Nothing, therefore, is better proved, than the metempsychosis of matter;† which warrants the belief that this religious dogma, like most of the fabulous worships and imaginations of antiquity, is but a veil ingeniously thrown by Philosophy, between Nature and the ignorant.

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* Beccher, *Physica subterranea.*

† Matter is eternal, in this sense, that the molecules of bodies merely pass from the one into the other; they survive the destruction, or rather the dissolution of organic and inorganic beings, when the former, ceasing to live, restore to the inexhaustible fund of Nature, those elements which she lends without ever parting with them.

Mancipio nulli datur, omnibus usu.

Lucret. lib. III.

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